VŠB – TECHNICAL UNIVERSITY OF OSTRAVA

FACULTY OF MECHANICAL ENGINEERING

ENERGY ENGINEERING

SOLÁRNÍ SOUSTAVA PRO RODINNÝ DŮM S ORIENTACÍ STŘECHY VÝCHOD - ZÁPAD

SOLAR SYSTEM FOR A FAMILY HOUSE WITH ORIENTATION OF ROOF EAST – WEST

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DIPLOMA THESIS SUPERVISOR: ING. ONDŘEJ NĚMČEK, Ph.D.

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VŠB - Technical University of Ostrava
Faculty of Mechanical Engineering
Department of Energy Engineering

Diploma Thesis Assignment

Student:	**Balaji Shanmugham, BE**
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The thesis language:	English

Description:

Design and calculate solar system for specified family house for preparation of hot water with use of thermosolar collectors. House is situated in Ostrava, it is inhabited whole-year by 5 persons. Solar coverage of heat demand for preparation of hot water – choose between 50 to 60 %.

Thesis will include:

1. Research focused on the possibilities of using solar radiation in the Czech Republic for the heat generation.
2. Variant design of the system with regard to the orientation and slope of the collector arrays, selection of optimal variants.
3. Design of the system, way of it use and operation, solution of disposition.
4. Determination of monthly and yearly profits based on a model processed using the database of a typical climate year.
5. Evaluation of the proposal from an economic and environmental point of view.
6. Graphic part - schema of engagement, solution of disposition. Materials and blueprints, tables and technical documentation.

References:

GODFREY, B. et al.: Renewable energy. Oxford: Oxford University Press, 2004. 452 p. ISBN 0-19-926178-4.
HEINLOTH, K. (editor). Energy Technologies. Subvolume C: Renewable Energy. Springer-Verlag Berlin Heidelberg 2006. ISBN-10 3-540-42962-x.
SORENSEN, B.: Renewable Energy. Burlington: Elsevier Academic Press, 2004. 952 p. ISBN 0126561532.
Materials and blueprints, tables and technical documentation.

Extent and terms of a thesis are specified in directions for its elaboration that are opened to the public on the web sites of the faculty.

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ANNOTATION OF DIPLOMA THESIS

SHANMUGHAM,B. *Solar System For A Family Housewith Orientation Of Roof East – West. Diploma Thesis.* Ostrava: VŠB –Technical University of Ostrava, Faculty of Mechanical Engineering, Department of Energy Engineering, 2019, 80 p. Thesis head: Němček,O.

The renewable sources of energy are the future of the world. With the world moving towards green and clean energy, it's time to find more efficient ways of using them. This thesis involves a typical Czech family of five members living in a house in Ostrava. In this project we will design the orientation of the roof in such a way that they are in the direction east-west giving the possibility of using the maximum efficiency possible. Also, the calculation is done for a full year and the profits are calculated monthly and yearly for the model of the solar collector used in the process. The main aim of the project is from the environmental point of view of using the best natural resources with maximum capacity and minimum losses. Also, the graphic part and the scheme of the solar collectors used will be discussed including the blueprints of the house and the technical documentation.

Key words: Solar energy, solar collector, alternate energy sources

ANOTACE DIPLOMA THESIS

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Obnovitelné zdroje energie jsou budoucností světa. Se světem směřujícím k zelené a čisté energii je čas najít účinnější způsoby, jak je používat. Tato práce zahrnuje typickou pětičlennou českou rodinu žijící v Ostravě. V tomto projektu navrhneme orientaci střechy tak, aby se nacházela ve směru východ - západ, což umožňuje využít maximální možnou efektivitu. Také výpočet se provádí za celý rok a zisk se vypočítává měsíčně a ročně pro model solárního kolektoru použitého v procesu. Hlavním cílem projektu je z hlediska životního prostředí využití nejlepších přírodních zdrojů s maximální kapacitou a minimálními ztrátami. Dále bude diskutována grafická část a schéma použitých solárních kolektorů včetně plánů domu a technické dokumentace.

Klíčová slova: Sluneční energie, solární kolektor, alternativní zdroje energie

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF GRAPHS

LIST OF VARIABLES

A	Area of the collector	m^2
Cp	Specific heat of fluid (water)	KJ/kgK
P	Pressure	Pa
ΔT	Temperature Difference	°C
GGh	Average hourly radiation intensity for global horizontal radiation	W/m^2
GDh	Average hourly radiation intensity for diffuse horizontal radiation	W/m^2
GGk	Average hourly radiation intensity for global radiation inclined	W/m^2
GDk	Average hourly radiation intensity for diffuse radiation inclined	W/m^2
GBn	Average hourly radiation intensity for direct normal radiation	W/m^2
-	Heat Demand	kWh
a1	Collector loss coefficient	W/m^2K
a2	Collector loss coefficient	W/ m^2K^2
T_1	Temperature of input cold water	°C
T_2	Temperature of output hot water	°C

INTRODUCTION

Energy is one of the most important things that every human needs to do his day to day work. To get the energy, we can either use renewable or non-renewable energy sources. The use of renewable energy sources is gradually increasing day by day. Renewable energies are the best and viable option to meet the large amount of energy needs which is easily affordable and viable. This is the future for sustainable development. The world is in a serious threat already since the amount of CO_2 released to the atmosphere has increased, melting of glaciers in the Antarctic region. Keeping everything in mind, the need to use the renewable energy sources should be increased tremendously.

Solar energy provides the world a green and clean energy. About 70% of our daily energy needs can be obtained easily through the solar panels if we are in the hot region. The effects of global warming which is the major problem all over the world, the conservation of the environment has become a major priority for all the countries. Also, the price of fossil fuels is increasing enormously due to the heavy consumption, which makes way for the various renewable energy sources to grow. This development will help us to shift to greener methods of energy. Even though the solar energy has many advantages it's not getting enough investments as it should get as the annual return of money for the total investment takes a huge amount of time.

Solar energy works by converting the sun's rays of heat and light into an electrical energy and further converting into chemical energy for storing it in a battery. The solar water heating system saves an average of 250 € per month. The content of the project involves a family house and their dependency on solar energy for the production of heat water including the amount of money they saved annually. The calculation of the system and its design and the optimal angle of orientation to achieve the maximum output is done thus enabling the people to save the planet from releasing harmful gases into the atmosphere thus contributing themselves to the part of the greener earth.

TYPES OF ENERGY EXISTING IN THE WORLD

Electricity is the most important thing for everybody in the planet. Life without producing and using them is almost practically impossible. There are two major ways to produce electricity

1. Renewable energy sources
2. Non-renewable energy sources

1. RENEWABLE ENERGY SOURCES

1.1 SOLAR ENERGY

It is the perfect example for a renewable source on the earth. We receive a lot of heat from the sun which we can try to convert and use it for our daily needs. The amount of heat we receive from the sun is per day is same as that of the amount of energy the population uses per year. If we can harness the amount of radiation completely it will be of great use to the entire human race and for our future. [1]

Fig. 1 A picture of the solar collector [2]

Solar Radiation

At present the sun radiates energy at the rate of 3.9 x 10^{26} W. At the top the earth's atmosphere an average power of 1353 W/m^2 is passing through a plane perpendicular to the direction to the direction of the sun. [3]

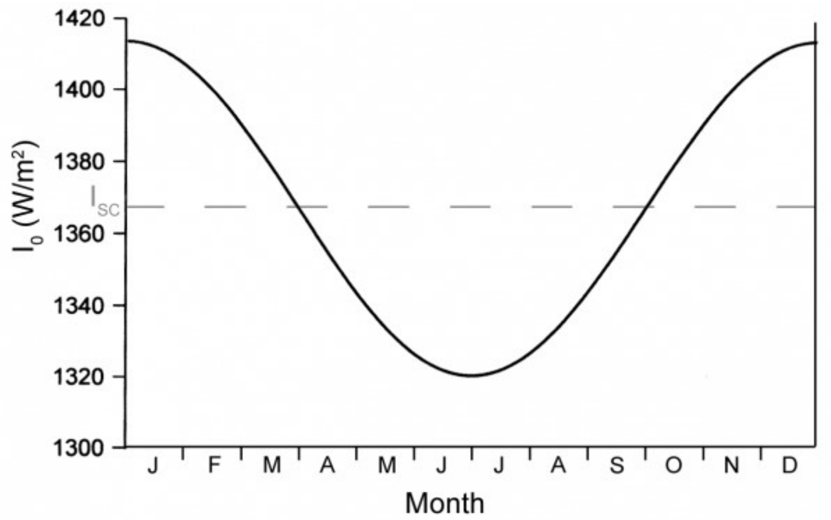


Fig. 2. Yearly variation in Solar Constant

1.2 WIND ENERGY

Wind energy is as important as solar energy. Our ancestors depended a lot on wind by using it in sailboats, to extract water from the pump deep underground. Like solar we will never lose the wind and it is one of the best renewable energy sources available in the planet. The main drawback of the wind energy is that the wind is not as constant as solar energy and it cannot be predicted correctly for most of the time.

It has many disadvantages but the main problem is to find an land that big to accommodate many windmills so that enough energy is produced for the huge investment of money.

Fig. 3 A picture of the windmill taken in The Netherlands (Author)

The installation cost of the wind energy and its components are high and the amount of energy recovered from it depends on the wind. Also, the installation cannot be wherever we want and the location of the plant is very important for it.

1.3 GEOTHERMAL ENERGY

It can be defined as the energy stored in the planet. The heat is constantly emitted towards the surface of the earth. It's a clean source of energy and it's also sustainable form of energy. The process involves a geothermal heat pump system, an air delivery system or called as ductwork and a heat exchanger. In summer, the process is overturned and the heat pump changes heat from the inside air into the heat exchanger. [4]

There are two major types of geothermal energy. The overall thermal efficiency is relatively low when compared to others which is about an average of 15%. The heat from the exhaust is not used properly until it is transported to other places where it can be used. The first geothermal energy was started in 1960 in The United States of America.

Fig. 4 Place where geothermal energy is extracted [1]

The heat removed from the indoor air during the summer can also be used to provide a free source of hot water. Thus, we also get a clean source of energy by generating electricity.

1.4 HYDRO POWER

Hydropower is the current or power which we get from the water flowing from one place to another place. No water is wasted in the production of electricity and as long as the water flows in the river, the water can be recycled back and the electricity can be produced.

2. NON-RENEWABLE ENERGY SOURCES:

The two main types of non renewable energy sources are coal and petroleum which are recklessly degrading due to their extensive use.

2.1 COAL

Coal is the most widely used energy sources used from the stone age. It is the most abundant natural resources available on earth. There are 4 different types of coal

- **Lignite** is the newest type of coal of all. It is soft and has a wide variety of color from black to shades of brown. It is also called as brown coal. Lignite is mainly used for power generation and accounts for 17% of the world's coal reserves.
- **Sub-Bituminous Coal** It burns more efficiently than other types of coal due to its low sulphur content. Sub-bituminous coal is used in generation of power and also in industrial process. This coal type makes up 30% of the world's coal available.
- **Bituminous coal** is firmer and darker than both lignite and sub-bituminous coal, and can be further sub-divided into two types: thermal and metallurgical. They have 52% of the total coal in the world.
- **Anthracite** is the maximum developed coal and it has the peak carbon content. It is often used for home heating accounting for only 1 % of the world's total coal. [5]

	Anthracite	Bituminous	Subbituminous	Lignite
Moisture (%)	3–6	2–15	10–25	25–45
Volatile matter (%)	2–12	15–45	28–45	24–32
Fixed carbon (%)	75–85	50–70	30–57	25–30
Ash (%)	4–15	4–15	3–10	3–15
Sulfur (%)	0.5–2.5	0.5–6	0.3–1.5	0.3–2.5
Hydrogen (%)	1.5–3.5	4.5–6	5.5–6.5	6–7.5
Carbon (%)	75–85	65–80	55–70	35–45
Nitrogen (%)	0.5–1	0.5–2.5	0.8–1.5	0.6–1.0
Oxygen (%)	5.5–9	4.5–10	15–30	38–48
Btu/lb	12,000–13,500	12,000–14,500	7500–10,000	6000–7500
Density (g/mL)	1.35–1.70	1.28–1.35	1.35–1.40	1.40–1.45

Fig. 5 Composition and Property ranges for various ranks of coal

2.2 PETROLEUM

Raw material for petrol are thick yellow coloured flammable liquids which are found beneath the earth. They are found in rare geological locations deep under the earth's surface. They are used as the main source for the energy required for transportation in the world. The name represents both crude oil (naturally occurring) and processed oils. The use of petroleum leads to global warming and it's the major issue on earth now.

Carbon ranges from 83 to 85%, Hydrogen between 10 to 14%, Nitrogen from 0.1 to 2%, Oxygen in the range of 0.05 to 1.5% and finally Sulfur from 0.05 to 6.0%. It is the most widely used primary sources all around the world. It is also the raw material for many chemical products, including medicines, diluters, manures, insecticides, and plastics.

To get the petroleum, oil wells are drilled to extract crude oil. Crude oil is the raw product which, when further cleaned and processed the we get petroleum. The alkanes also known as paraffins have a general formula of C_nH_{2n+2}. The transportation all around the world hugely depends on crude oil and its by-products. [6]

3. SOLAR WATER HEATING WORKING

Solar water heating systems use solar panels or collectors. They are usually fixed or placed on top of the roof or in the nearby lawn if the area surrounding it is very big. The collectors collect the heat from the sun and use it to heat the water. An overhead water collector or a cylinder is placed where the water starts to heat.

There are two types Flat Plate Collectors and Evacuated Tubes

3.1 FLAT TYPE OVERHEAD WATER COLLECTOR

The flat plate water collector is suitable for residential or commercial solar water heating projects.

- Black surface which absorbent of the incident solar energy.
- Tubes filled with heating fluid to transfer the heat from the collector.
- Support structure to protect the mechanisms and keeping it upright.
- Covering it with insulator to reduce heat losses.
- Glazing acts as a transparent layer that transmits energy to the absorber, and also stops radiative and convective heat loss from the surface.

WORKING OF THE FLAT PLATE COLLECTOR

The flat plate collector operates and reach a maximum efficiency when the temperature is in the range of 30 ^{o}C to 80 ^{o}C. The transport material is made of glass, some foil made from polymers and some aerogels to absorb more heat.

The black surface consists of a large heat absorbing plate, usually made of a large sheet of copper or aluminium because they are good conductors of electricity. Since blackened surface absorbs additional heat than the other colour it is the most widely used one. This blackened heat absorbing surface and has several copper pipes or copper tubes with heating fluid which is used to transfer heat from the collector. The copper tubes are directly connected or soldered to the absorber plate.

Air based collectors are used for heating buildings and drying crops. Liquid based collectors are used for heating swimming pools. The liquid-based collector can further be categorized into two types – Glazed and Unglazed. Glazed is for indoor swimming pool heating and unglazed is for outdoor swimming pool heating.

Some advantages of the flat-plate collectors are that they are:

- They are easy to manufacture
- Collect both beam and diffuse radiation
- Low cost availability
- Little maintenance
- Fixed permanently

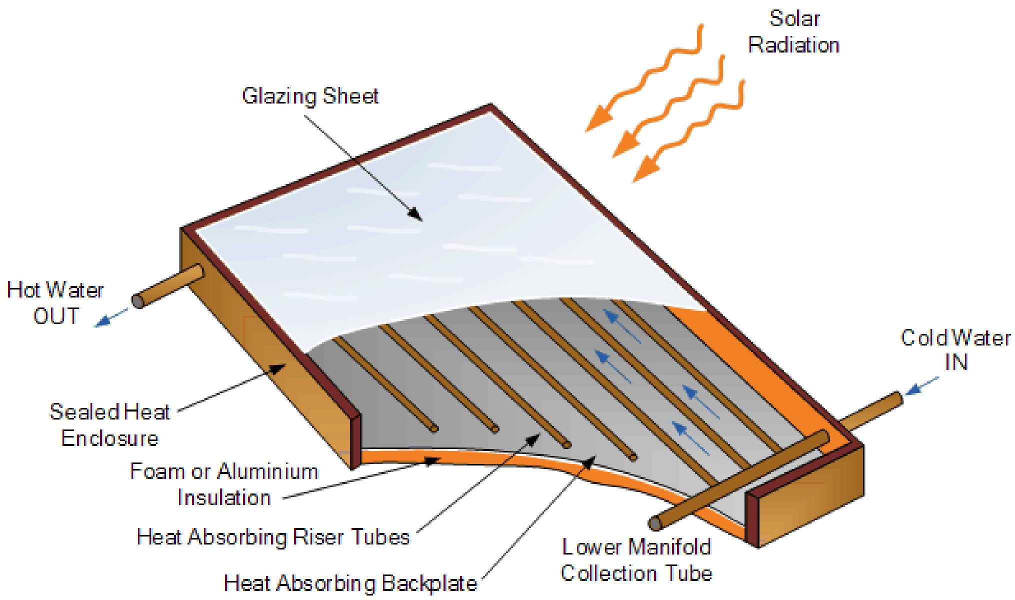


Fig. 6 Sectional view of the solar collector [7]

The tubes and the absorber plate are covered with an insulated metal with a sheet of glazing material. It does not act as a conductor but keeps the material safe. There is an airgap present between the plate and glazing material and this traps the heat preventing it to dissipate back into the atmosphere. The absorber collects the heat from the sun, gets heated up and transfers the heat to the fluid. [7]

There are two types of heat transfer system in the flat plate collector

- Direct hot water systems
- Indirect hot water systems

3.1.1 DIRECT HOT WATER SYSTEM

It is also called as open loop system. This system uses a pump to circulate the water. The cold water available in the house is pumped to the central storage heater and then it passes through the solar collector for heating. The water gets heated up and leaves the flat plate collector and returns back to the tank flowing for a continuous time till it gets heated up. The mechanics used in this type of heating is similar to that of the boiler application except here the solar rays is the main heat source.

The major drawback to this application is that it is prone to freeze damage. Even though the pump can be used to recirculate the water back to heating again, they are still limited to the areas that do not freeze during an average year.

For a small family house, a 12-volt pump can be used which can be powered. Since the water is pumped directly from the house, other chemicals to protect and clean the water for protection like chlorine cannot be added because of this.

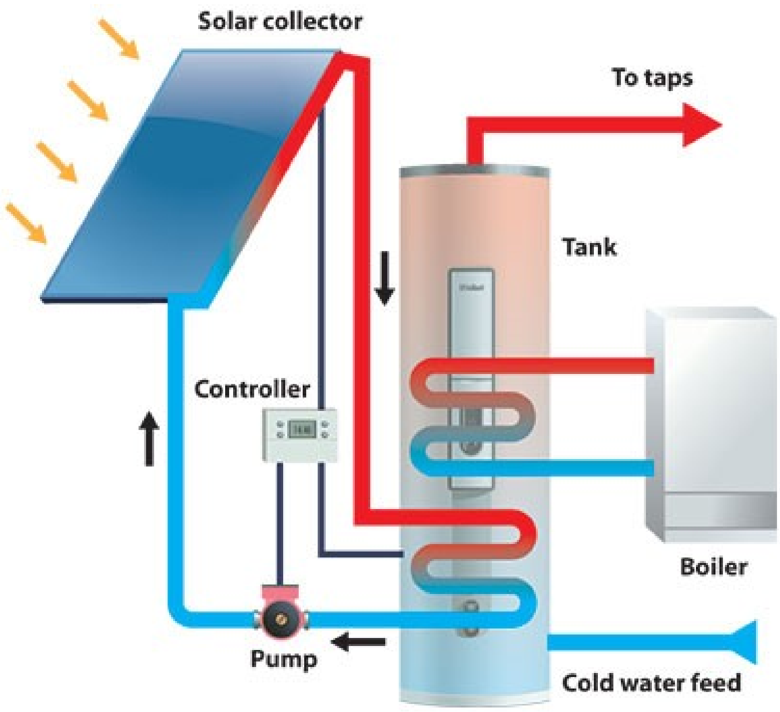


Fig. 7 Working of solar collectors [8]

In the passive direct hot water system or open loop control systems, they use natural force of gravity to help circulate the water around the system. The water heated by the sun is done by the convection and through the solar collectors and it enters the storage tank situated above. Flat plate collectors can be installed in many number of ways which depends on the choice of the people. It can be installed on top of the roof, hung on side of the walls, if there is an open lawn available for a big house, the solar collectors can be installed on the open ground too. It depends of the size of the collector.

The pupose of the absorber is to absorb as much as the incident solar radiation and re-emit as less as possible and allow efficient transfer of heat to a working fluid. The materials used for absorber plates include copper,aluminium and stainless steel. [9]

3.1.2 INDIRECT HOT WATER SYSTEM

They are called as closed loop system. This system uses a heat exchanger which is distinct from the solar flat plate collector. They require pumps to circulate water as they need to frequently transported between the heat exchangers and the heat collector. The system contains an antifreeze solution, which is a 50% mixture of glycol and water

- Solar liquid collectors can be divided by:
- Heat transfer agents
    - Liquid
    - Air
- Glazing
    - Without glazing
    - Simple
    - Multilayer
    - Structure
- Construction
    - Flat
    - Tubular
    - Concentration
    -

- Absorber
    - Plastic
    - Metallic - non-selective
    - Metal - selective
    - Accumulation
- Fill pressure
    - Atmospheric
    - Sub atmospheric (vacuum)

One of the main advantages to this closed loop indirect heating system is that the antifreeze solution gives full year-round operation in areas where the temperature always dips down below the freezing point and also to protect the system from corrosion of the collectors by untreated tap water containing gases and various dissolved salts.

The main advantage of a forced circulation indirect hot water system is that an existing domestic water available in the heating system can easily be converted to solar heating of the water just by adding a flat plate collector and a single pump as most homes use gas or oil-fired boilers as well as a hot water storage tank with built-in heat exchanger coil.

The system is also very much likely to be more efficient and the hot water storage tank can be fixed anywhere as per the customer needs in the home because it does not need to be higher than the collectors as in the previous passive or thermosyphon system. Some designs use a small low voltage pump and photovoltaic panel alongside the collector making the system more efficient and greener. For bigger fittings and in cold environments the hot-water tanks are comprised underneath the roof inside buildings, so forced circulation indirect solar water heating is the norm. Problem is that the closed-loop system is reliant on electricity for the circulating pump which may is costly.

4. ORIENTATION OF THE ROOF

The orientation and placement of the roof is very important and plays a major role in the solar energy for the family house. The maximum power output and efficiency can be achieved only by calculating the exact angle and the position of it that needs to be fit in. It will harness the power if the rays are perpendicular. The ultra-modern expensive solar collectors use solar tracking systems to significantly increase energy production by following the sun's rays. [10]

DIRECTION EAST-WEST

The direction east- west is chosen because the sunrises from the east and sets in the west. Bearing this in mind the orientation of the roof is made in this direction so that the solar collectors can be placed on the roof. The maximum output can be obtained both during morning and evening and also since the sun's rays are perpendicular to the collector and they can manage to get the required household electricity. By placing in this direction, the required energy to produce the hot water can be done both morning and afternoon. Also, the excess energy available can be utilized for some other purposes. [11]

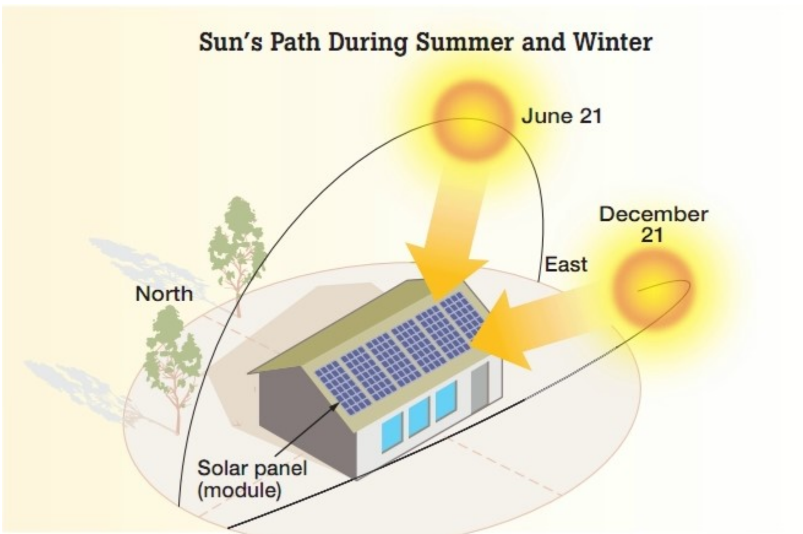


Fig. 8 Sun's path in different seasons [12]

Although the sun rises in the east and sets in west, it's not entirely perfectly in this direction. The course of the sun deviates to other directions over the period of the year continuously. So, the most perfect trajectory is impossible to calculate but it's possible to calculate the average path of it for all over the year and we will use it to get the most efficiency.

4.1 CALCULATING SOLAR PANEL ANGLE

The solar collector panel angle of your solar system varies depending on which part of the world we are present. Solar panels will give the maximum efficiency energy output when they are directly facing the sun or the panels are perpendicular to the sun's rays. The sun always keeps moving transversely in the sky and will be low or high in the sky depending on the time of the climate, season, time and day. For that reason, the ideal angle keeps changing and is never fixed.

To get the maximum rays on the panel throughout the day, we have to govern what direction the panels must be placed to face it and also main importantly to estimate an optimal tilt angle.

They depend on two most important things:

1. The global position of us.
2. And what season of the year we need the solar energy.

5. TECHNICAL CALCULATIONS

5.1 INTRODUCTION

The solar energy radiation data for the region Ostrava, Czech Republic is obtained from the Institute of Meteorology, METEONORM, Atlas of Solar Radiation.

Regarding to information relating to the supply water temperature (temperature of the network), values in °C, for the case of Ostrava, were provided by the "Department of Energy of the University of Ostrava". [13]

The sequence in which the computational models are joined in producing hourly radiation data on an arbitrarily tiled surface at a site for which no dimensions are available, are the followings:

1 - Interpolation with monthly average value model *Gh,* Ta: Space dependent interpolation of horizontal radiation and temperature based on weather data taking altitude, topography, region, and other parameters into account.

2 – Hourly value generator Gh, Ta: Stochastic generation of time dependent global horizontal radiation and temperature data having a quasi-natural distribution and an average monthly value equal to the average value over 20 years.

3 – Radiation resolution Gh Dh, Bn: resolution of global radiation into diffuse and direct components.

4 – Radiation on inclined surface with skyline effect, hourly value model Gk: calculation of hemispherical radiation on arbitrary orientated surfaces taking the reduction due to skyline profile into account. [14]

For our project we have considered a house present in the Ostrava,Czech Republic. The house has 5 persons in total inhabited whole year.

Longitude and latitude of Ostrava

- Longitude of Ostrava: 18.262524 ° E
- Latitude of Ostrava: 49.820923 ° N

The following example shows the steps taken to obtain data from our project:

- Choose a language (English)

- Choose type of site Cities: the city Ostrava is chosen. The coordinates and altitude of the city center are given for each city (Ostrava).

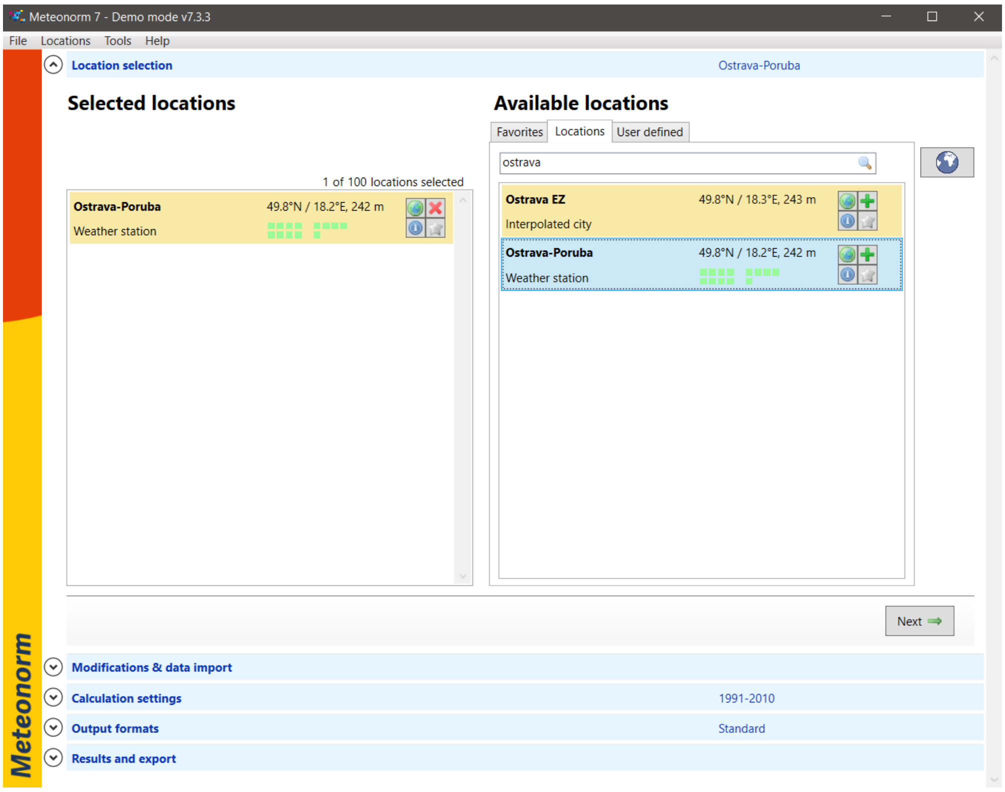


Fig. 9 Choosing the location of the house

- In the data form different models, time periods, and additional settings can be chosen and own data can be imported.

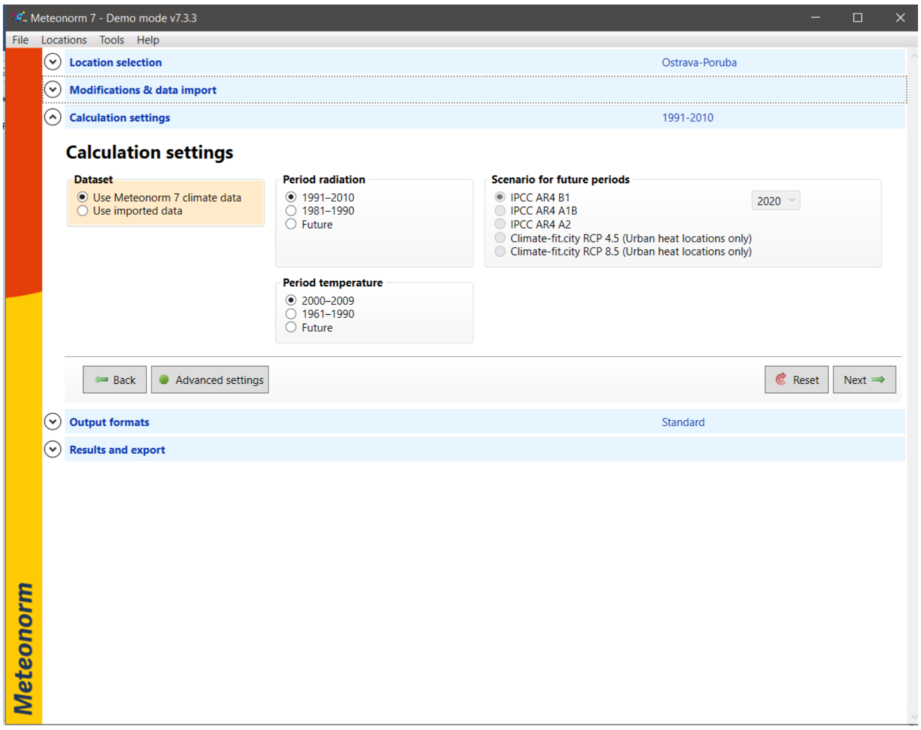


Fig. 10 Choosing the recorded radiation and temperature from the region

-In the format form, choose output format Standard and select the plane orientation and the azimuth. In the project have been studied different inclinations as (30°, 40°, 50°, 60°).

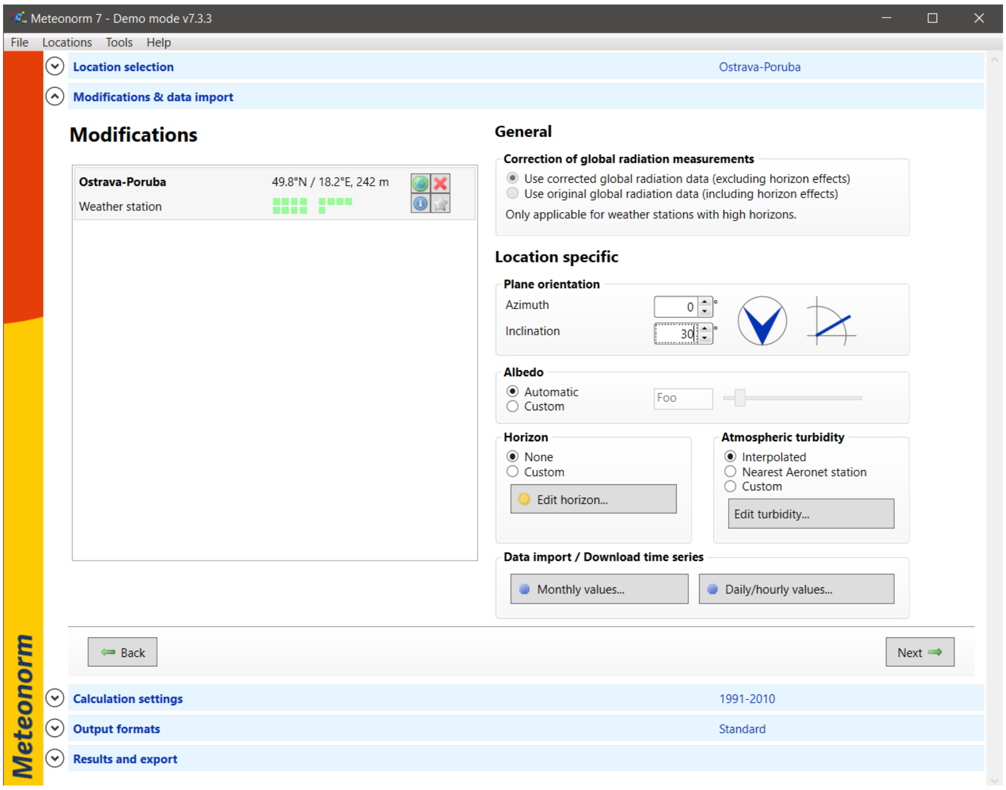


Fig. 11 Modifying inclination angle required

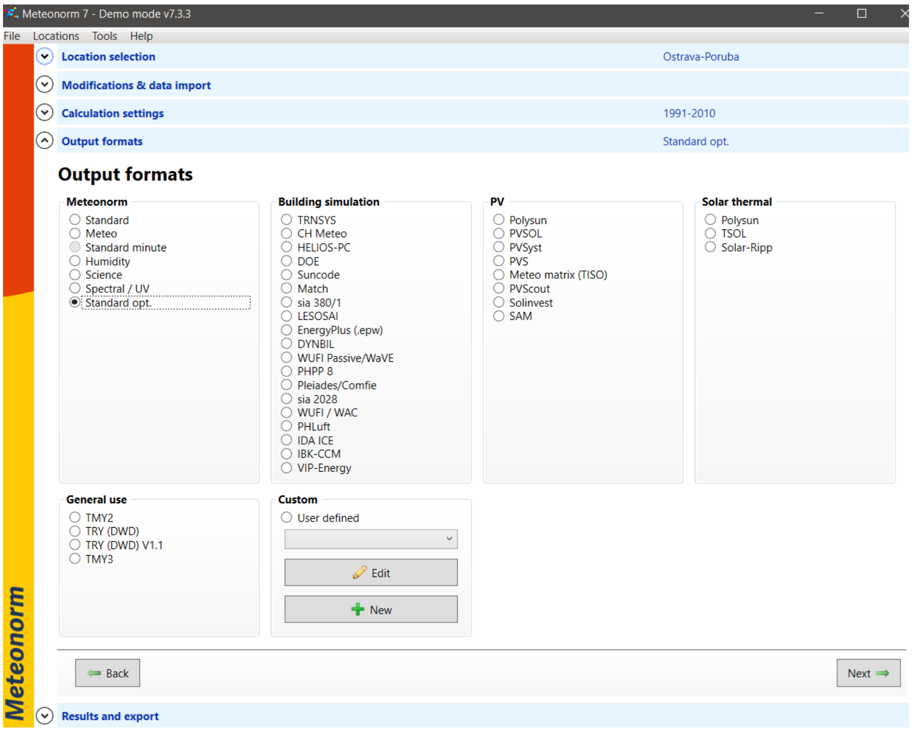
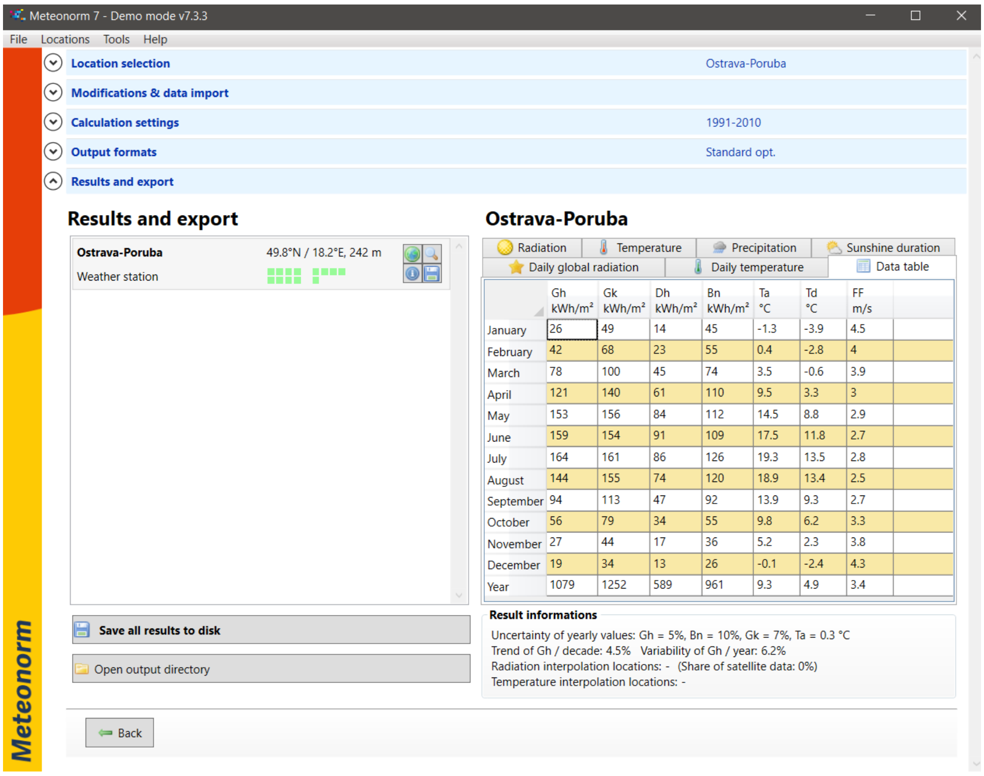


Fig. 12 Standard selection of output

- The monthly values are first interpolated, then the hourly global horizontal radiation values and temperature are calculated, and finally the radiation on the inclined surface. The results are shown in the display.



	Gh kWh/m²	Gk kWh/m²	Dh kWh/m²	Bn kWh/m²	Ta °C	Td °C	FF m/s
January	26	49	14	45	-1.3	-3.9	4.5
February	42	68	23	55	0.4	-2.8	4
March	78	100	45	74	3.5	-0.6	3.9
April	121	140	61	110	9.5	3.3	3
May	153	156	84	112	14.5	8.8	2.9
June	159	154	91	109	17.5	11.8	2.7
July	164	161	86	126	19.3	13.5	2.8
August	144	155	74	120	18.9	13.4	2.5
September	94	113	47	92	13.9	9.3	2.7
October	56	79	34	55	9.8	6.2	3.3
November	27	44	17	36	5.2	2.3	3.8
December	19	34	13	26	-0.1	-2.4	4.3
Year	1079	1252	589	961	9.3	4.9	3.4

Fig. 13 Exporting the results in the form of data table.

The number family members living in the house is five. They will live all around the year in the house, so the installation of the solar panels will have the annual coverage for the need of hot water preparation. The average daily consumption of water for a person will be 60 liters/day.

The average temperature of supply of cold water every month in a year is as follows.

AVG TEMPERATURE OF SUPPLY OF COLD WATER (CZECH REPUBLIC) °C	
JANUARY	**8.3**
FEBRUARY	**7.7**
MARCH	**8.1**
APRIL	**9.4**
MAY	**11.3**
JUNE	**13.3**
JULY	**14.8**
AUGUST	**15.4**
SEPTEMBER	**15**
OCTOBER	**13.6**
NOVEMBER	**11.7**
DECEMBER	**9.7**

Table 1 Average temperature of supply of cold water [13]

The house of the inhabitants will have the roof in the direction of East- West so that a large amount of radiation can be extracted easily from the solar panels.

5.2 CALCULATION OF ENERGY DEMAND

The calculation of energy demand for the house is very crucial as it determines the amount of energy essential to heat the hot water consumed in the family house.

For this calculation, it is necessary to determine some parameters, like desired temperature of hot water (60^0C), volume of water used as a reference per person and day (60L/person*day), and supply temperature of cold water (both defined in data item).

The first is to calculate energy demand generated by the heating of the DHW Energy Demand in DHW facilities is given by the following expression:

$$\boldsymbol{Demand} = \frac{\textbf{Daily consumption} * \textbf{Cp} * \boldsymbol{\Delta}\textbf{T} * \textbf{Number of days}}{\textbf{3600}}$$

..... *(Eqn.1)*

Where:

Daily consumption: It is the diary consumption of DHW [liters/day]

Cp: Specific heat of fluid (water) = 4.18 $\frac{kJ}{kg*°C}$

ΔT: Temperature difference between water supply and consumption (60^0C)

Number of days: Number of days in the month.

3600: Is the conversion factor to go from kJ to kWh

For January month,

$$\text{Demand} = \frac{300 * 4.18 * 51.75 * 31}{3600}$$

= 558.82 kWh/ month

Monthly energy consumption is calculated using the following expression:

$\mathbf{Q = m \cdot c_e \cdot \Delta T}$

Where:

m : Mass of hot water consumption

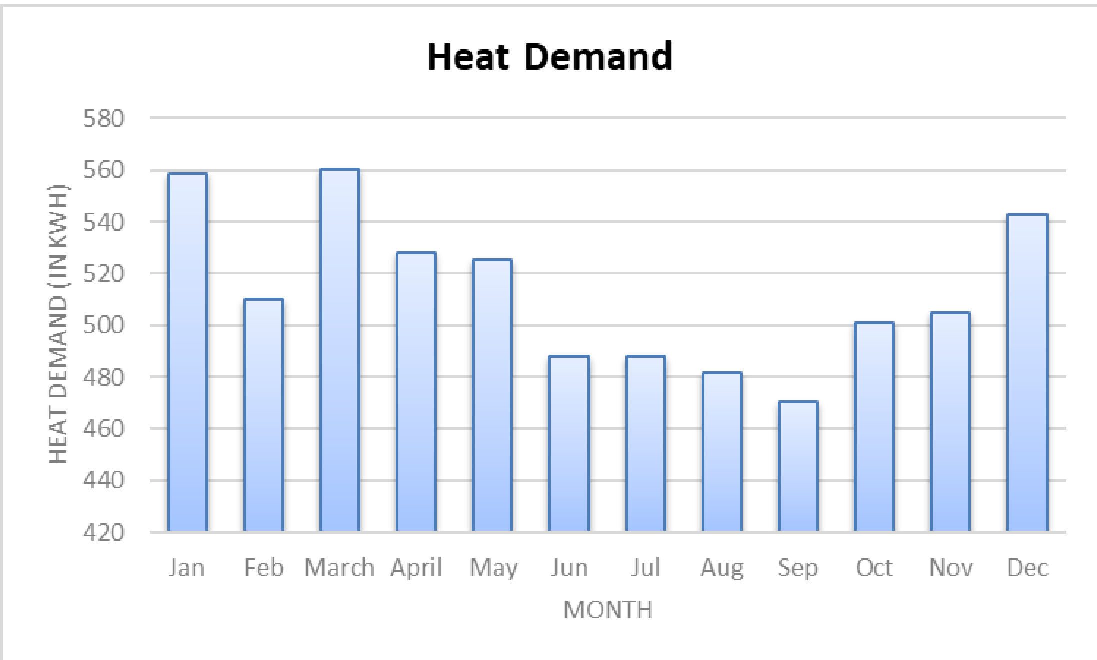
$\mathbf{c_e}$: Specific heat of water

ΔT : Difference between design temperature of hot water and supply temperature of cold water ($T_{design} – T_{supply}$)

So, for our house, the values will be as follows.

MONTH	*JAN*	*FEB*	*MARCH*	*APRIL*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*
Days	31.00	28.00	31.00	30.00	31.00	30.00	31.00	31.00	30.00	31.00	30.00	31.00
Hours in the month	744.00	672.00	744.00	720.00	744.00	720.00	744.00	744.00	720.00	744.00	720.00	744.00
Input of of cold water [ºC]	8.25	7.69	8.11	9.44	11.35	13.31	14.80	15.41	14.97	13.60	11.69	9.73
Output of hot water [°C]	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00
Temp difference [ºC]	51.75	52.31	51.89	50.56	48.65	46.69	45.20	44.59	45.03	46.40	48.31	50.27
Daily Consumption	300	300	300	300	300	300	300	300	300	300	300	300
Heat Demand	558.82	510.16	560.37	528.32	525.33	487.88	488.11	481.49	470.56	501.00	504.86	542.78

Table 2 Heat Demand for each month



Graph 1. Graph showing the heat demand for each month in a year

The program provides the following outputs data:

- **M**-Month.
- **D**-Day.
- **H**-Hour.
- **Hy**-Hour in the year.
- **Ta-**Hourly ambient temperature
- **GGh**-Average hourly radiation intensity for global horizontal radiation [W/m^2].
- **GDh**-Average hourly radiation intensity for diffuse horizontal radiation [W/m^2].
- **GGk**-Average hourly radiation intensity for global radiation inclined [W/m^2].
- **GDk**-Average hourly radiation intensity for diffuse radiation inclined [W/m^2].
- **GBn**-Average hourly radiation intensity for direct normal radiation [W/m^2].
- Heat demand
- Useful gain from the system
- Maximum gain from the system

5.3 CALCULATIONS

The calculation is taken for the solar collector which is placed in the direction west inclined at an angle of 30° at the specific month "April"

1. **Q_{total} is** the total energy production obtained through the solar radiation in a month. Its unit is in Wh/m^2.

   Q_{total} = Σ Total energy produced in April month .... *(Eqn. 2)*

   $Q_{total} = 54864.85\ Wh/m^2$

2. **Sum of Ggh** – The average hourly radiation intensity for global horizontal radiation in Ostrava. This value is obtained from Meteonorm and the total sum for 24 hours per day including all the days in the month is added. The unit for this is W/m^2.

   $Q_{\Sigma Ggh}$ = Σ Total average hourly radiation intensity for global horizontal in April month in ostrava .... *(Eqn. 3)*

   $\Sigma Ggh = 110164\ W/m^2$

3. **Sum of Ggk –** The average hourly radiation intensity for global radiation inclined in Ostrava. This value is obtained from Meteonorm and the total sum for 24 hours per day including all the days in the month is added. The unit for this is W/m2. [15]

   $\mathbf{Q_{\Sigma Ggk}}$ **=** Σ Total average hourly radiation intensity for global radiation in April month in ostrava ….………………. *(Eqn. 4)*

   $\Sigma Ggk = 102885\ W/m^2$

4. **Efficiency –** The ratio of $\mathbf{Q_{total}}$ to that of the average hourly radiation intensity for global radiation inclined in Ostrava.

   $$\text{Efficiency (\%)} = \frac{\text{Qtotal}}{\text{Sum of Ggk}} \quad \text{………………………………………………………… (}\mathit{Eqn.5}\text{)}$$

   $$= \frac{54864.85}{102885}$$

   $$= 54\%$$

5. Total number of persons in the house – **5 .** According to our assumption, in the house situated in Ostrava, a total of 5 persons in the house throughout the entire year.

6. Consumption of water per person per day – **60 liters of Water per day**.

   The average Czech person consumed 89.2 liters of water per day in 2018. Water from public water supply systems does not supply 5% of the Czech population. The Czech Statistical Office (CZSO) published the 2018 figures on water consumption on May 2,2018. We have taken into account only the hot water,so the household peoplw will have access to use cold water separately. Also the water is not for drinking,the people will have to depend on another source to get clean source of fresh water. [16]

7. The desired output temperature of water is **60°C.** We set the output temperature as 60°C as it is the ideal temperature and the water remains a little hot through out the night as well. The skin doctors recommend the temperature less than 50°C to prevent one from burning. [17]

8. Losses in the system. From the literature "Solar Energy Assessment of heating systems - Simplified calculation procedure. ÚNMZ 2009", the loss value is taken which is the standard value set at **0.15** [18]

9. Demand for the heat required

For April Month,

$$\text{Demand} = \frac{\text{Daily consumption}*\text{Cp}*\Delta\text{T}*\text{Number of days}*\text{No.of persons}}{3600} \quad \text{.......... } (Eqn.6)$$

$$= \frac{60 * 1.414 * 50.6 * 30 * 5}{3600}$$

= 530.85 kWh/month

10. Demand including the heat losses. There will be losses in the system. So, we should consider the losses into account and calculate the real heat demand of the system.

Heat loss in the solar system = Z =0.15

Demand including the heat loss $= \frac{\text{Heat demand}}{(1-\text{losses})}$ .... (*Eqn.7*)

$= \frac{530.85}{(1-0.15)}$ kWh/month

= 624.53 kWh/month

11. Necessary solar collector area required for the demand heat.

Demand area$= \frac{\text{Heat demand with losses}}{\text{Qtotal}} * 1000$ .... (*Eqn.8*)

$= \frac{624.53}{55864.85} * 1000$

= 11.18 m^2

The area needed in the winter months is much higher than in the summer months. It is because solar radiation in winter month is much lower than summer month. Furthermore, the temperature of supply of cold water, is lower in winter months, so we need to apply more energy to heat the water until production temperature of hot water

Because of that, dimensioning of area of solar collector, we do respect months of more heat (we chose the month of April), even though oversupply the installation does not produce significant increases of efficiency of the coldest month, that is where in more important the auxiliary energy. April month, show us that the area need is 10.865 of solar collector. So, area collectors must be whole multiple of the area of aperture of the collector selected for the installation.

Absorber Area	2.204 m^2
Number of Pieces	5
Total area of solar collector	11.02 m^2

Table 3. Parameters solar collector selected [19]

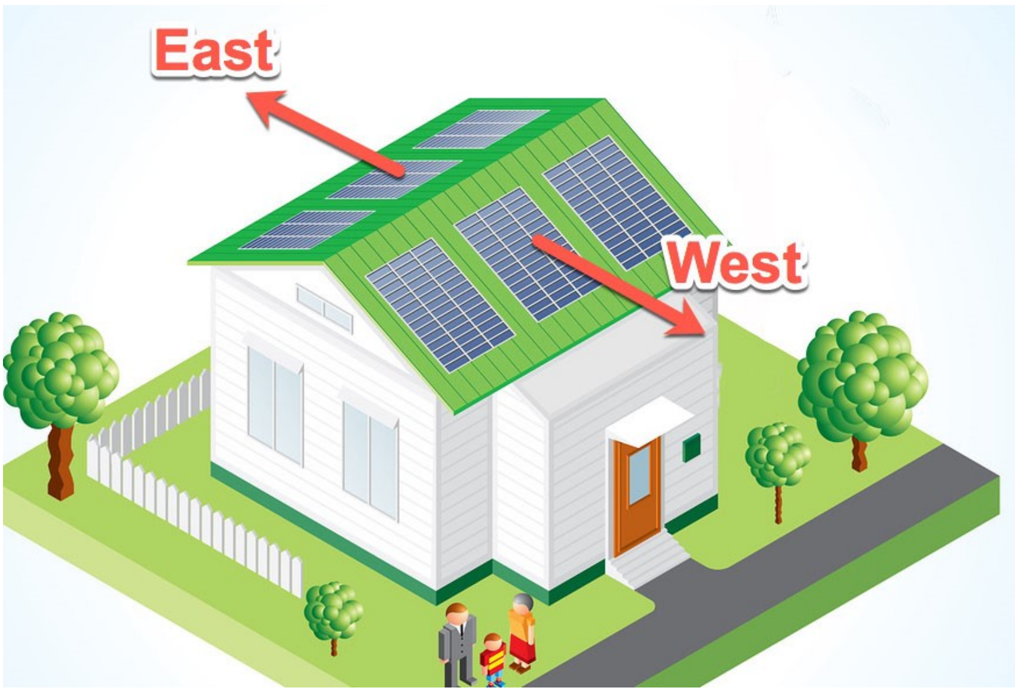


Fig. 14 isometric view of the position of solar collectors on the house [20]

12. Maximum gain from the system

$$\text{Max gain from the system} = \frac{\text{Design area of the collector}}{\text{Qtotal}} * 1000 \;\text{..........}(\textit{Eqn.9})$$

$$= \frac{10.87}{54864.85} * 1000$$

$$= 606.97 \text{ kWh}$$

13. Oversupply or Lack of energy from the system

Since we use solar energy, the energy we gain from the system will not be constant and it fluctuates during winter/summer season and also during day/night. We have calculated the energy demand required for the specific month (Eqn.6) and also maximum gain from the system (Eqn.8), by calculating the difference between the two values, we can find if we want extra source of heat or not.

Lack = Maximum gain from the system – Demand with heat losses …………(*Eqn.10)*

= 606.97 kWh - 624.53 kWh

= -17.55 kWh

The negative sign(-ve) states that we need an auxillary heating device to achieve the exact desired temperature during the april month. If we get a positive sign (+ve) sign,then there is excess amount of energy gained from the system.

14. Useful gain from the system.

During the summer system,there will be an excess amount of heat energy obtained from the system. This extra heat energy cannot be used and it's a waste. But during the winter season,the amount of energy generated will be low, hence we need to use all the energy generated

If oversupply < Zero, we use maximum gain

If oversupply < Zero , we use demand with heat loss ………………………………..(*Eqn.11)*

For April,

The maximum gain is 606.97 kWh

The heat demand with losses is 624.53 kWh

Lack of energy is -17.55 kWh

Since its lack of energy,we use the maximum gain from the system.

15. Solar fraction

The amount of energy obtained from the solar energy system which can be used as a source of energy is known as Solar Fraction.

Solar Fraction $= \frac{\text{Useful gain from the system}}{\text{Demand with heat losses}}$ * 100 ……………………..(*Eqn.12)*

Solar Fraction $= \frac{606.97}{624.537}$ * 100

= 0.97

Solar fraction depends on lot of factors. Higher the solar fraction, more useful energy can be obtained from Solar radiation

16. Pump working hours

The pump will work only when there is enough amount of heat from the atmosphere available which can increase the water temperature. It varies time to time. For the month we considered ,we should do the summation of all working hours .

Pump working hours = Σ(Working hours of each day in the month) ………(*Eqn.13)*

= 245 hours.

17. Real pump working hours

The real pump values are determined by useful work done, that is exact hours of pump operation excluding the overproduction factor.

Ratio of useful energy required = $\frac{\text{Useful gain from the system}}{\text{Maximum gain from the system}}$ …………………(*Eqn.14)*

$= \frac{620.99}{969.73}$

= 0.64

Real pump working hours = Max.hour pump can work* Useful ratio of work

= 0.64*245

= 206 hours

This value is calculated only duriing the months of May, June, July and August where we had overproduction.

The above steps and calculations is similar for all the different angles and the direction. So, using the above methods and formulas, the calculation for the angles East 30°, East 40°, East 50°, East 60° and also for West 30°, West 40°, West 50° and West 60° is done and I have shown the results in tabular columns so that we can differentiate the results easily.

Characteristics parameters of the collectors studied:

SOLAR COLLECTOR USED - SOLAR POWER SK500N

- Gross area (m^2) = 2.204 m^2 - The total size of the surface of the collector that faces the sun. This comprises any part of the collector structure that is fundamental to its right operation that cannot be detached from the collector itself.
- Absorber area (m^2) = 2.173 m^2 - Absorber Area is the size of the black absorber surface inside the glass. [21]
- Aperture area (m^2) = 2.204 m^2 - The area of the glazing is the part of the collector that is designed to trap solar radiation. This is the area which we use for calculations.
- Optical efficiency: η_0= 0.806
- Collector loss coefficients: a1 = 3.68 (W/m^2K), a_2 = 0.0072 (W/ m^2K^2)

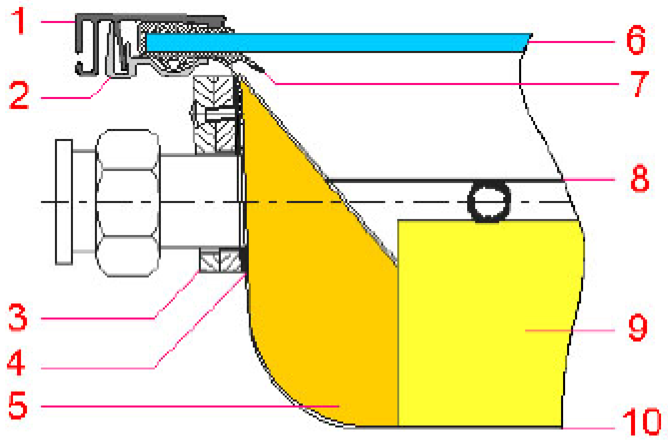


Fig. 15. Schematic diagram of the collector

In which

1. Cover rail
2. Glass fixing profile
3. Flange Plate
4. Sealing
5. Lateral Thermal Insulation
6. Glazing
7. Sealing profile
8. Absorber
9. Thermal insulation
10. Casing

The selection of the solar collectors plays a major role in achieving the maximum efficiency.

COLLECTOR DATA	
Model	SK 500N
Type	Flat Plate Collector
AREA	
Gross area	2.573 m^2
Aperture area	2.204 m^2
Absorber area	2.173 m^2
EFFICIENCY COEFFICIENTS	
Conversion factor η0	0.806
Collector loss coefficients:	a1 = 3.68 (W/m^2K),
Collector loss coefficients:	a2 = 0.0072 (W/m^2K^2)

Table 4 Selected solar collector properties [19]

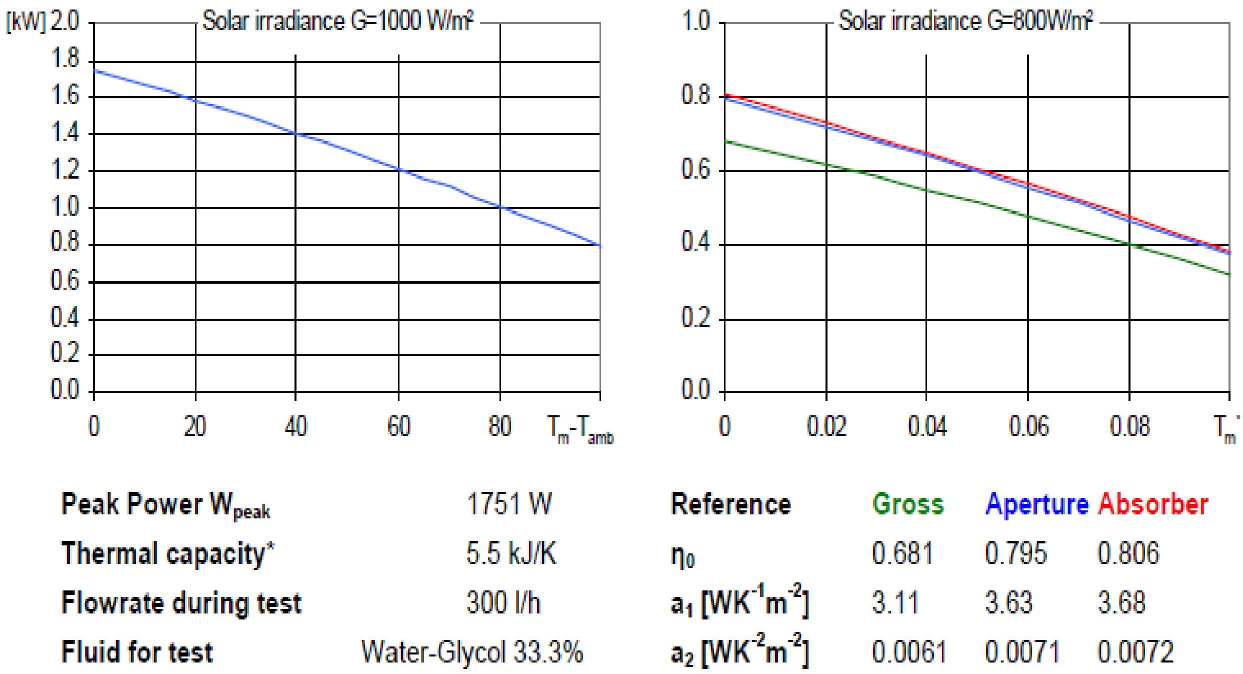


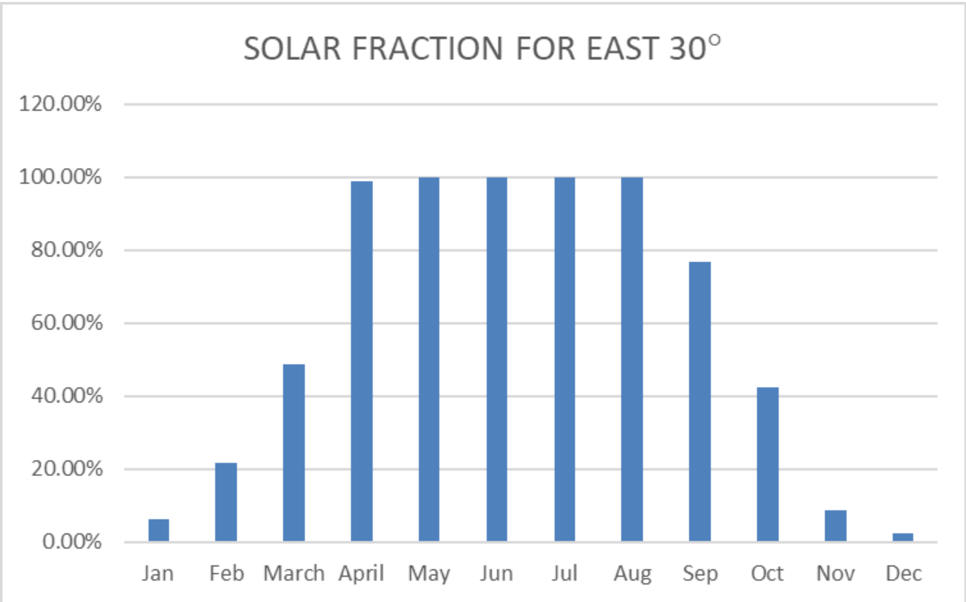
Fig. 16 Relative efficiency and peak power collector

The results for various inclinations for the direction

East 30

	Solar Fraction [%]
January	6%
February	21%
March	49%
April	99%
May	100 %
June	100 %
July	100%
August	100%
September	77%
October	42%
November	9%
December	2%
TOTAL	58%

Table 5. Solar fraction for East 30°



Graph 2. Graph showing solar fraction for East 30°

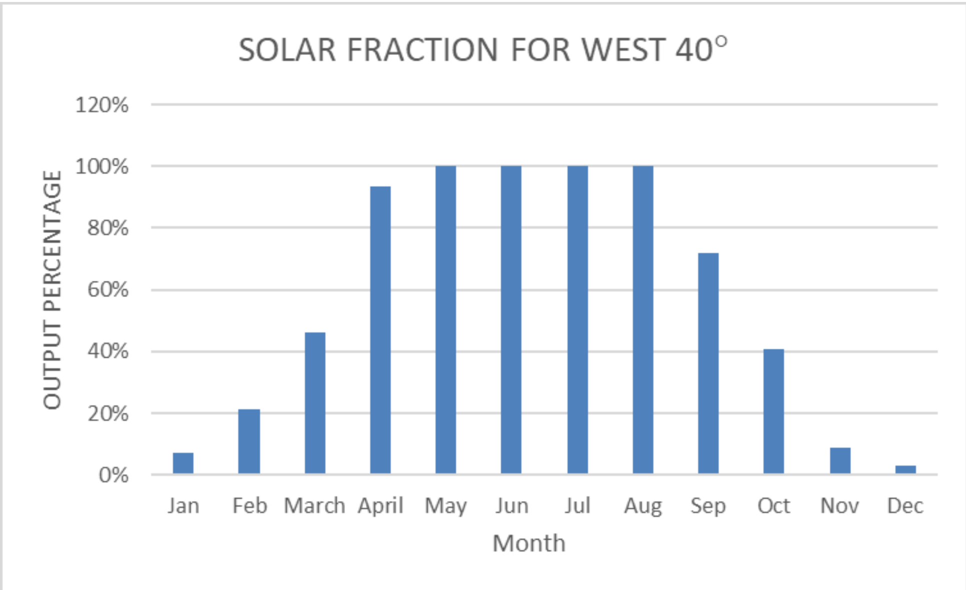
Summary for the orientation- East 30°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	3702	11902	29259	56042	87967	89199	91546	84192	38794	22744	4727	1419
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	23707	39875	70639	104327	143839	144193	146540	134184	77746	53853	23098	16472
efficiency	0.16	0.30	0.41	0.54	0.61	0.62	0.62	0.63	0.50	0.42	0.20	0.09
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	178.42	50.68	22.64	11.14	7.06	6.47	6.30	6.76	14.34	26.04	126.26	452.13
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	40.80	131.16	322.43	617.58	969.39	982.97	1008.84	927.80	427.52	250.64	52.09	15.64
oversupply/lack	-619.77	-472.04	-339.99	-6.94	348.40	406.24	431.84	358.63	-128.74	-341.59	-544.71	-625.98
Useful gain from system [kWh]	40.80	131.16	322.43	617.58	620.99	576.73	577.00	569.17	427.52	250.64	52.09	15.64
Solar fraction	0.06	0.22	0.49	0.99	1.00	1.00	1.00	1.00	0.77	0.42	0.09	0.02

Table 6 Summary – for the inclination East 30°

East 40

	Solar Fraction [%]
January	7%
February	21%
March	46%
April	93%
May	100%
June	100%
July	100%
August	100%
September	72%
October	41%
November	9%
December	3%
TOTAL	56%

Table 7. Solar fraction for East 40°



Graph 3. Graph showing solar fraction for East 40°

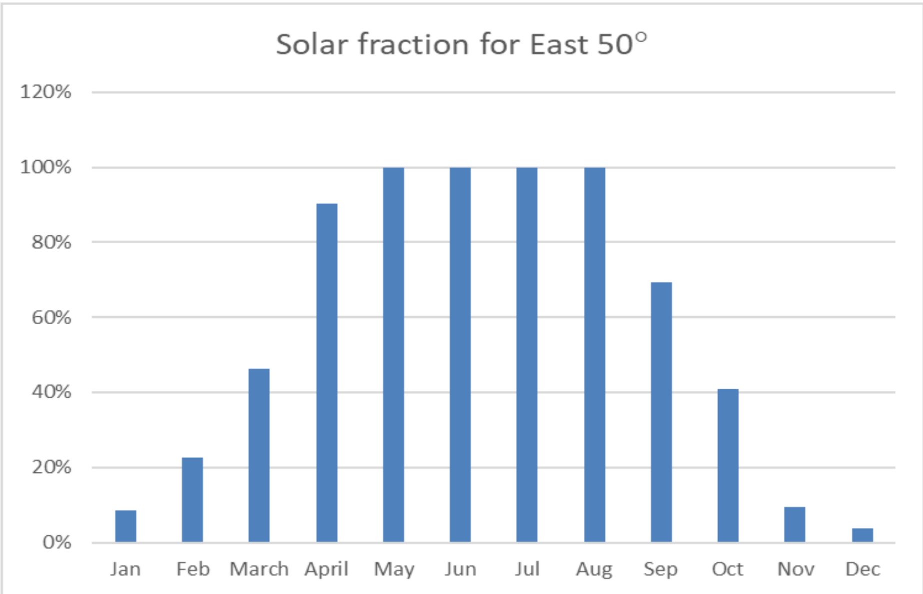
Summary for the orientation East 40°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	4255	11668	27852	52918	83400	84934	86649	80934	36193	21889	4775	1718
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	23696	39342	68565	100231	138048	138744	140339	129966	74274	52275	22515	16383
efficiency	0.18	0.30	0.41	0.53	0.60	0.61	0.62	0.62	0.49	0.42	0.21	0.10
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	155.25	51.70	23.78	11.80	7.45	6.79	6.66	7.03	15.37	27.06	124.99	373.42
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	46.89	128.58	306.93	583.15	919.06	935.97	954.88	891.89	398.85	241.22	52.62	18.93
oversupply/lack	-613.68	-474.61	-355.49	-41.37	298.07	359.24	377.88	322.72	-157.40	-351.01	-544.17	-622.68
Useful gain from system [kWh]	46.89	128.58	306.93	583.15	620.99	576.73	577.00	569.17	398.85	241.22	52.62	18.93
Solar fraction	0.07	0.21	0.46	0.93	1.00	1.00	1.00	1.00	0.72	0.41	0.09	0.03

Table 8 Summary – for the inclination East 40°

East 50

	Solar Fraction [%]
January	8%
February	23%
March	46%
April	90%
May	100%
June	100%
July	100%
August	100%
September	69%
October	41%
November	9%
December	4%
TOTAL	57%

Table 9 Solar fraction for East 50°



Graph 4. Graph showing Solar Fraction for East 50°

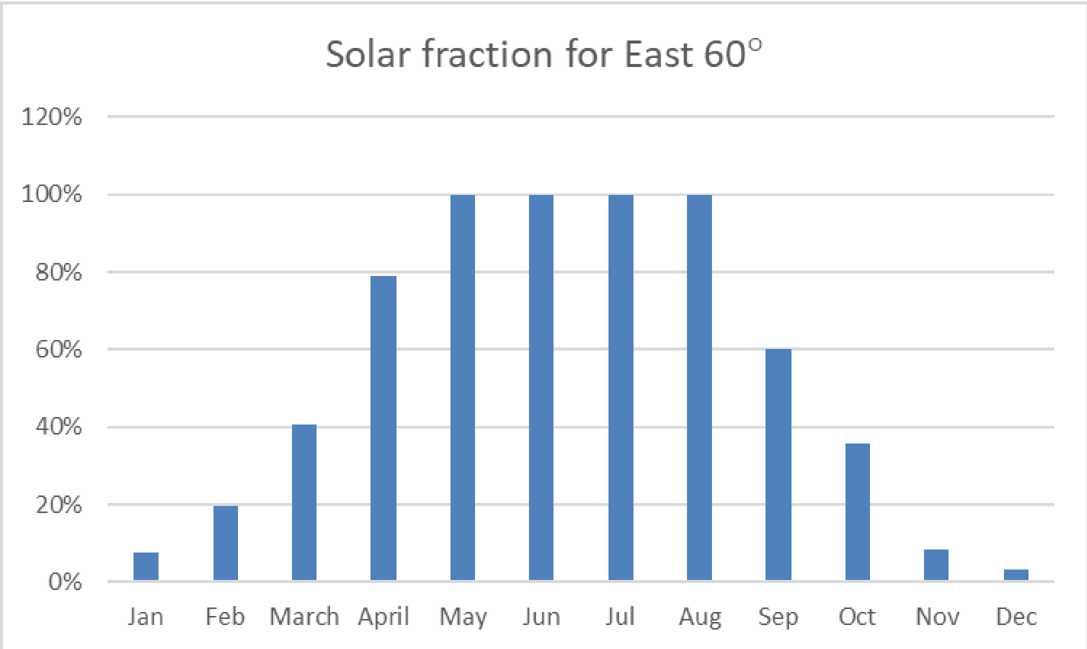
Summary for the orientation East 50°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	5075	12360	27888	51198	79930	81634	82918	78346	34967	21935	5081	2139
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	23779	38444	66234	95284	131041	132000	133031	124322	70413	50532	21765	16084
efficiency	0.21	0.32	0.42	0.54	0.61	0.62	0.62	0.63	0.50	0.43	0.23	0.13
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	130.15	48.80	23.75	12.20	7.77	7.06	6.96	7.26	15.91	27.00	117.45	299.95
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	55.93	136.21	307.32	564.20	880.83	899.61	913.76	863.37	385.34	241.73	56.00	23.57
oversupply/lack	-604.64	-466.98	-355.10	-60.32	259.84	322.88	336.76	294.21	-170.91	-350.50	-540.80	-618.05
Useful gain from system [kWh]	55.93	136.21	307.32	564.20	620.99	576.73	577.00	569.17	385.34	241.73	56.00	23.57
Solar fraction	0.08	0.23	0.46	0.90	1.00	1.00	1.00	1.00	0.69	0.41	0.09	0.04

Table 10 Summary – for the inclination East 50°

East 60

	Solar Fraction [%]
January	8%
February	20%
March	41%
April	79%
May	100%
June	100%
July	100%
August	100%
September	60%
October	36%
November	8%
December	3%
TOTAL	53%

Table 11. Solar fraction for East 60°



Graph 5. Graph showing solar fraction for East 60°

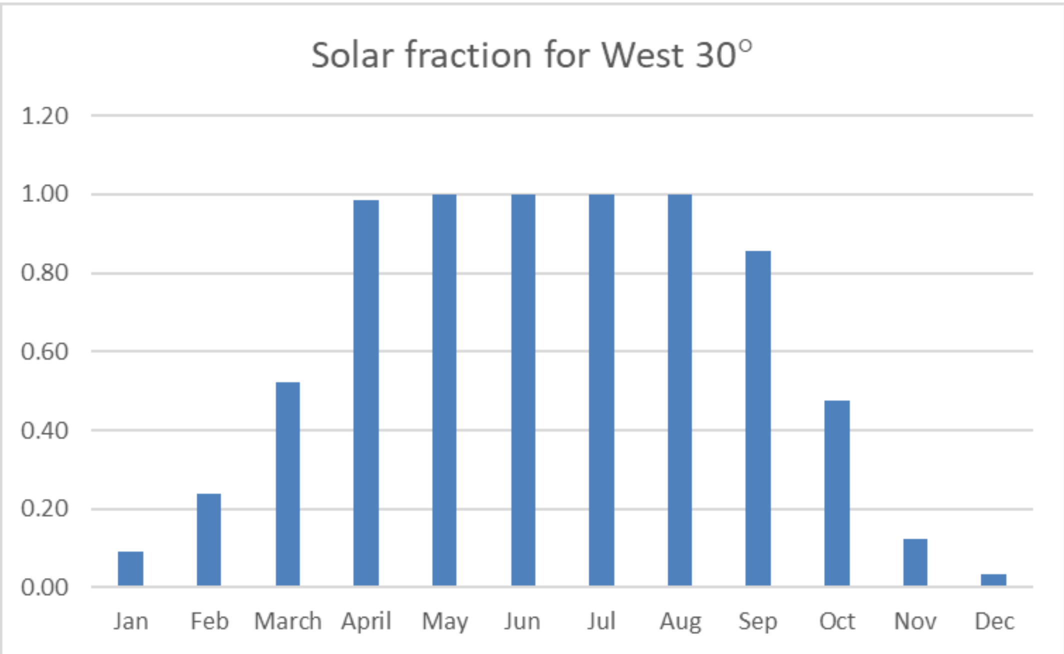
Summary for the orientation East 60°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	4582	10836	24367	44641	71589	73537	74412	71173	30268	19251	4495	1799
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	23554	37540	63392	89266	123045	124071	124733	117355	66142	48198	20759	15628
efficiency	0.19	0.29	0.38	0.50	0.58	0.59	0.60	0.61	0.46	0.40	0.22	0.12
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	144.16	55.67	27.19	13.99	8.67	7.84	7.75	8.00	18.38	30.76	132.75	356.72
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	50.49	119.41	268.52	491.95	788.91	810.38	820.03	784.33	333.55	212.14	49.54	19.82
oversupply/lack	-610.08	-483.78	-393.90	-132.58	167.92	233.65	243.03	215.16	-222.70	-380.09	-547.25	-621.80
Useful gain from system [kWh]	50.49	119.41	268.52	491.95	620.99	576.73	577.00	569.17	333.55	212.14	49.54	19.82
Solar fraction	0.08	0.20	0.41	0.79	1.00	1.00	1.00	1.00	0.60	0.36	0.08	0.03

Table 12 Summary – for the inclination East 60°

West 30

	Solar Fraction [%]
January	9%
February	24%
March	51%
April	99%
May	100%
June	100%
July	100%
August	100%
September	86%
October	47%
November	12%
December	3%
TOTAL	60%

Table 13. Solar fraction for West 30°



Graph 6. Graph showing solar fraction for West 30°

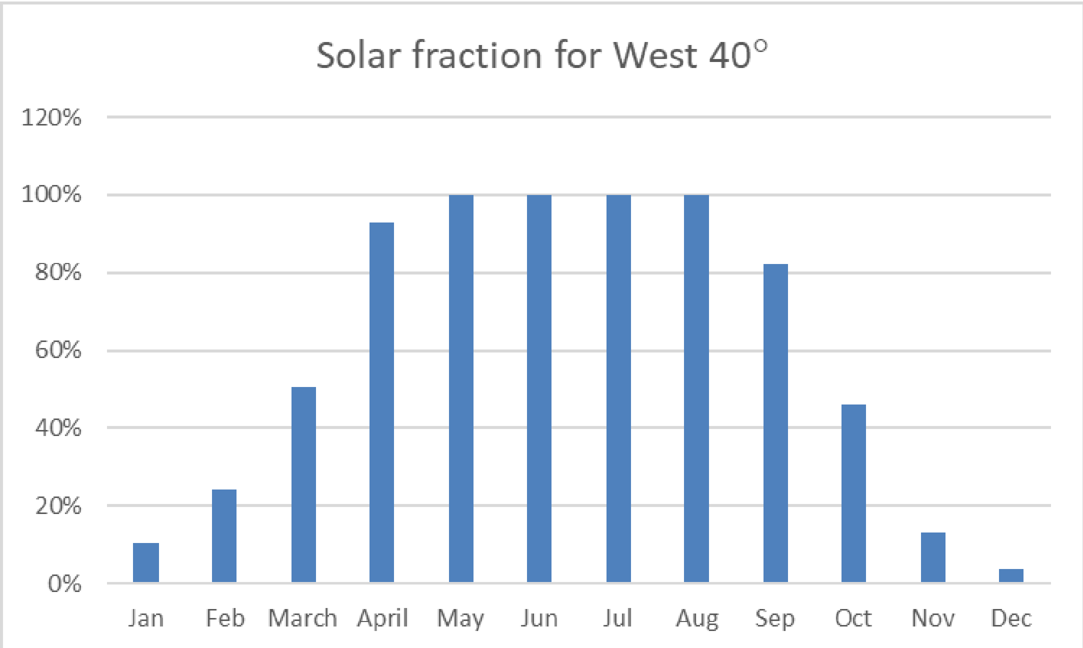
Summary - Results of Inclination for West 30°												
Parameters / Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	5455	13083	31309	55865	87998	83963	91284	78390	43273	25490	6679	1898
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	26160	41145	72398	102885	142840	135206	144386	124880	82306	56351	25770	16880
efficiency	0.21	0.32	0.43	0.54	0.62	0.62	0.63	0.63	0.53	0.45	0.26	0.11
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	121.08	46.11	21.16	11.18	7.06	6.87	6.32	7.26	12.85	23.23	89.35	338.03
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	60.12	144.17	345.02	615.63	969.73	925.27	1005.95	863.86	476.87	280.90	73.61	20.92
oversupply/lack	-600.45	-459.02	-317.40	-8.90	348.74	348.55	428.95	294.69	-79.38	-311.33	-523.19	-620.70
Useful gain from system [kWh]	60.12	144.17	345.02	615.63	620.99	576.73	577.00	569.17	476.87	280.90	73.61	20.92
Solar fraction	0.09	0.24	0.52	0.99	1.00	1.00	1.00	1.00	0.86	0.47	0.12	0.03

Table 14 Summary – for the inclination West 30°

West 40

	Solar Fraction [%]
January	10%
February	24%
March	51%
April	93%
May	100%
June	100%
July	100%
August	100%
September	82%
October	46%
November	13%
December	4%
TOTAL	59%

Table 15. Solar fraction for West 40°



Graph 7. Graph showing Solar Fraction for West 40°

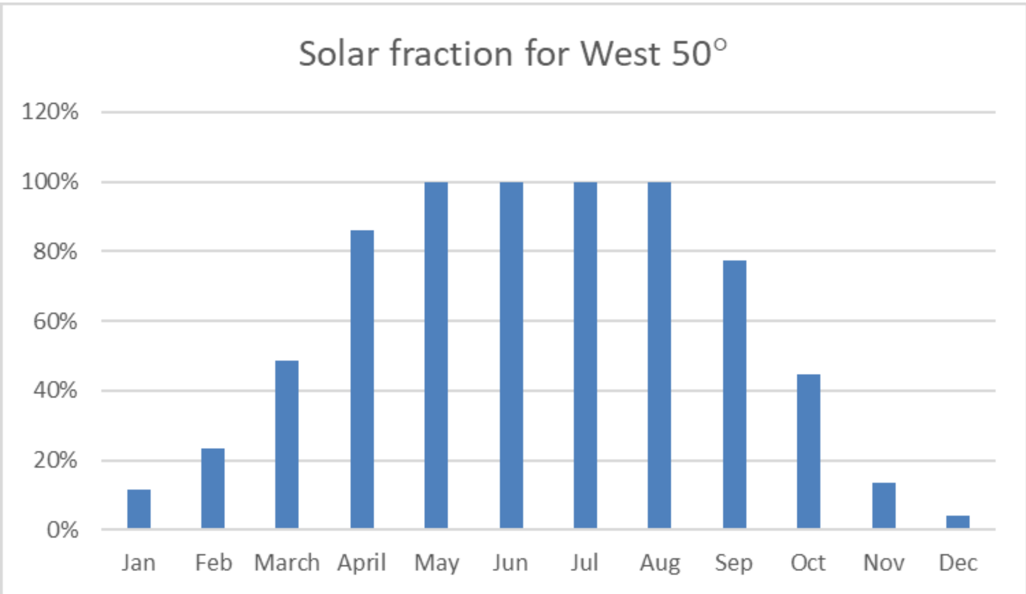
Summary for the orientation West 40°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	6235	13198	30394	52662	83567	78632	86239	73618	41532	24805	7048	2154
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	26444	40750	70779	98562	137038	128036	137856	118723	79780	55159	25606	16645
efficiency	0.24	0.32	0.43	0.53	0.61	0.61	0.63	0.62	0.52	0.45	0.28	0.13
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	105.95	45.70	21.79	11.86	7.43	7.33	6.69	7.73	13.39	23.88	84.67	297.87
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	68.71	145.44	334.94	580.33	920.91	866.53	950.36	811.27	457.69	273.35	77.67	23.74
oversupply/lack	-591.86	-457.76	-327.48	-44.19	299.92	289.80	373.36	242.11	-98.57	-318.88	-519.12	-617.88
Useful gain from system [kWh]	68.71	145.44	334.94	580.33	620.99	576.73	577.00	569.17	457.69	273.35	77.67	23.74
Solar fraction	0.10	0.24	0.51	0.93	1.00	1.00	1.00	1.00	0.82	0.46	0.13	0.04

Table 16 Summary – for the inclination West 40°

West 50

	Solar Fraction [%]
January	11%
February	23%
March	48%
April	86%
May	100%
June	100%
July	100%
August	100%
September	77%
October	45%
November	13%
December	4%
TOTAL	58%

Table 17. Solar fraction for West 50°



Graph 8. Graph showing Solar Fraction for West 50°

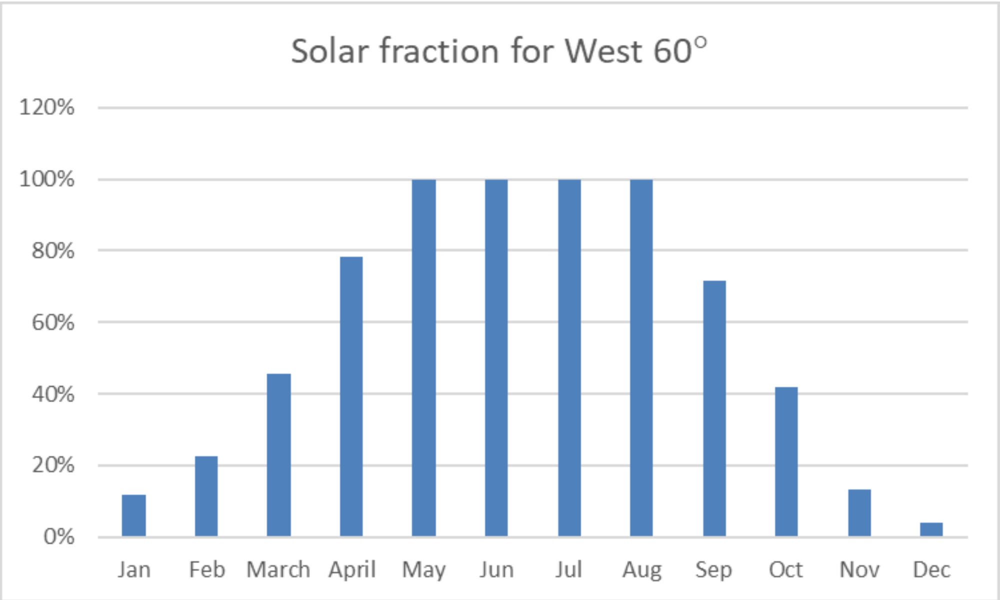
Summary for the orientation West 50°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	6806	12843	29111	48759	78326	72528	80341	68203	39075	23967	7272	2252
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	26802	39960	68726	93423	130349	120248	130443	111912	76304	53604	25108	16378
efficiency	0.25	0.32	0.42	0.52	0.60	0.60	0.62	0.61	0.51	0.45	0.29	0.14
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	97.06	46.97	22.75	12.81	7.93	7.95	7.18	8.35	14.24	24.71	82.06	284.89
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	75.00	141.53	320.81	537.32	863.15	799.26	885.36	751.59	430.61	264.12	80.14	24.82
oversupply/lack	-585.57	-461.67	-341.61	-87.20	242.16	222.53	308.36	182.43	-125.64	-328.11	-516.65	-616.80
Useful gain from system [kWh]	75.00	141.53	320.81	537.32	620.99	576.73	577.00	569.17	430.61	264.12	80.14	24.82
Solar fraction	0.11	0.23	0.48	0.86	1.00	1.00	1.00	1.00	0.77	0.45	0.13	0.04

Table 18 Summary – for the inclination West 50°

West 60

	Solar Fraction [%]
January	12%
February	23%
March	45%
April	78%
May	100 %
June	100%
July	100%
August	100%
September	72%
October	42%
November	13%
December	4%
TOTAL	56%

Table 19. Solar fraction for West 60°



Graph 9. Graph showing Solar Fraction for West 60°

Summary for the orientation West 60°												
Parameters/Month	***Jan***	***Feb***	***March***	***April***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Q_{tot} [Wh/m2]	7121	12383	27329	44456	72133	65802	73763	62623	36131	22463	7232	2348
Sum of Ggh	24518	41620	74390	110164	152502	149654	155431	137544	84952	57286	25190	17083
Sum of GgK	26737	39116	65947	87744	122522	111713	122024	104818	72115	51171	24284	15951
efficiency	0.27	0.32	0.41	0.51	0.59	0.59	0.60	0.60	0.50	0.44	0.30	0.15
Demand [kWh/month]	561.49	512.71	563.06	530.85	527.84	490.22	490.45	483.79	472.82	503.40	507.28	545.38
Demand [kWh/month] + losses	660.57	603.19	662.42	624.53	620.99	576.73	577.00	569.17	556.25	592.23	596.79	641.62
necessary m2	92.76	48.71	24.24	14.05	8.61	8.76	7.82	9.09	15.40	26.36	82.52	273.25
Design area of solar collector	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Max gain from system [kWh]	78.48	136.46	301.16	489.90	794.91	725.14	812.87	690.11	398.16	247.55	79.70	25.88
oversupply/lack	-582.09	-466.74	-361.25	-134.62	173.92	148.41	235.87	120.94	-158.09	-344.68	-517.09	-615.74
Useful gain from system [kWh]	78.48	136.46	301.16	489.90	620.99	576.73	577.00	569.17	398.16	247.55	79.70	25.88
Solar fraction	0.12	0.23	0.45	0.78	1.00	1.00	1.00	1.00	0.72	0.42	0.13	0.04

Table 20 Summary – for the inclination West 60°

5.4 EFFICIENCY OF THE SYSTEM

FOR THE EAST DIRECTION				
INCLINATION	30°	40°	50°	60°
EFFICIENCY THROUGHT THE YEAR	58%	57%	57%	53%

Table 21 Efficiency for east facing solar collectors

FOR THE WEST DIRECTION				
INCLINATION	30°	40°	50°	60°
EFFICIENCY THROUGHT THE YEAR	60%	59%	58%	56%

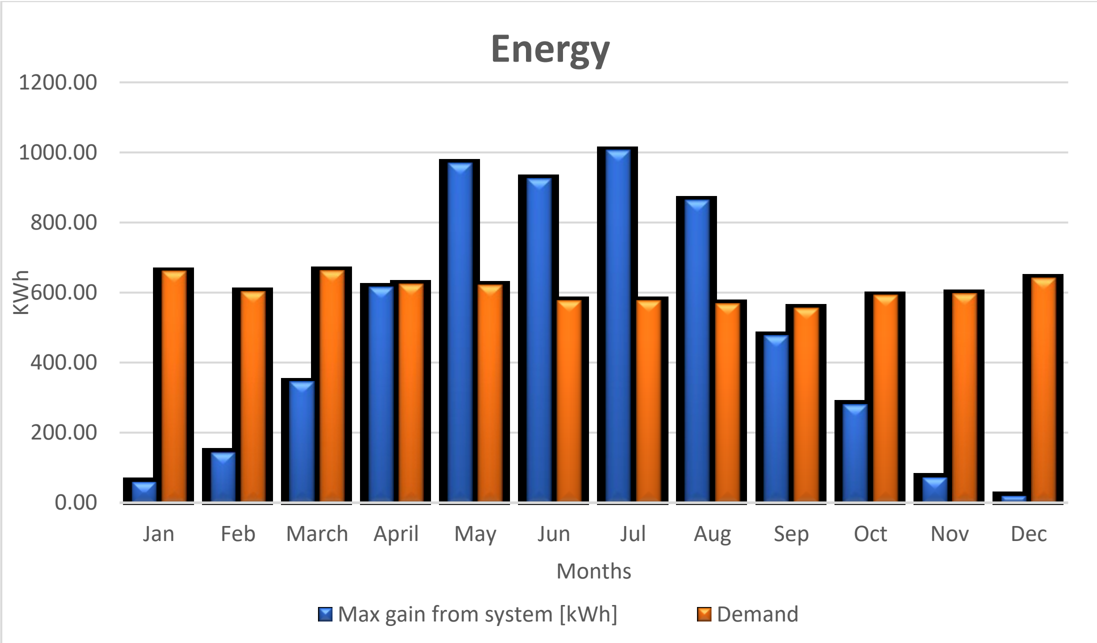
Table 22 Efficiency for west facing collectors

For the best placement of the solar collector, 8 specific angles that are East 30°, 40° ,50°,60° and also for West 30°, 40° ,50°, 60° . Of the all above did calculations for the various angles for the both the directions – East & West, the maximum solar fraction was obtained from the West 30°. So, the solar collector will be installed facing west in the direction of inclination of 30°.

Some of the advantage of choosing this angle was

1. Having 100% of cover during the months of April, May, June, July and August.
2. The energy obtained throughout the year using the solar system was 60%.

For the West 30°,



Graph 10. Max energy gained from the system along with Heat demand for West 30°

During the winter season, the heat demand will be higher than the heat gained from the system. At this time, an external auxiliary source to heat the water is necessary. It can be an electric water or a gas boiler. The required power output is calculated and the suitable heater /boiler is used.

This boiler can also be used to heat the water if the desired temperature is not achieved or if the hot water demand is high and the water stored in the tank is already used. The auxiliary source can be an electric hot water heater or gas boiler and it depends on the user.

6. CONNECTION OF THE SOLAR COLLECTORS

6.1 CONNECTIONS

The solar collectors can be connected in two main ways. They are organized in different number of rows and columns. They can be connected in parallel or series type or also combination of both as parallel- series type.

Rows of collectors can be connected together in parallel, in series or series-parallel, off valves should be installed at the entrance and exit of the different batteries of collectors and between pumps, so that could be used for isolation of these components in maintenance works and replacement.

The number of collectors that can be connected in parallel will take into account the constraints of the manufacturer. The maximum limit for the collectors to be coupled in series is three. In some cases of applications for industrial cooling and absorption, whether it is justified, this number may be increased to four. In the event that the application is DHW should not connect more than two collectors in series. There will be a system to ensure equal water travel in all the collectors. The downside to series systems is shading problems. When panels are wired in series, they all in a sense depend on each other. If one panel is shaded it will affect the whole string. This will not happen in a parallel connection. [22]

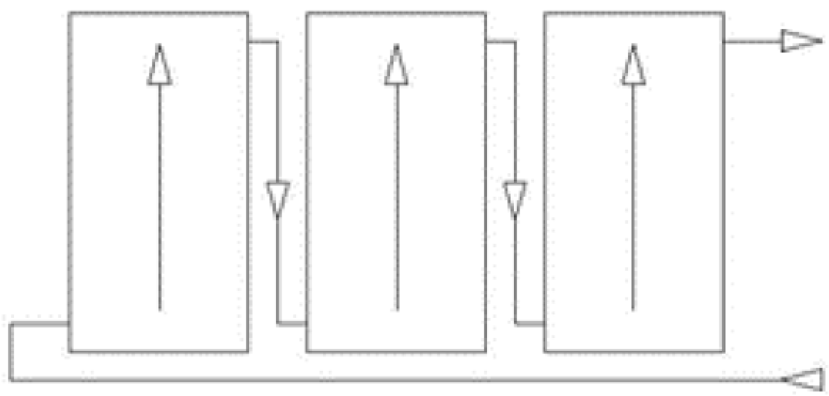


Fig. 17 Collectors in Series

The downside to parallel systems is that high amperage is difficult to travel long distances without using very thick wires.

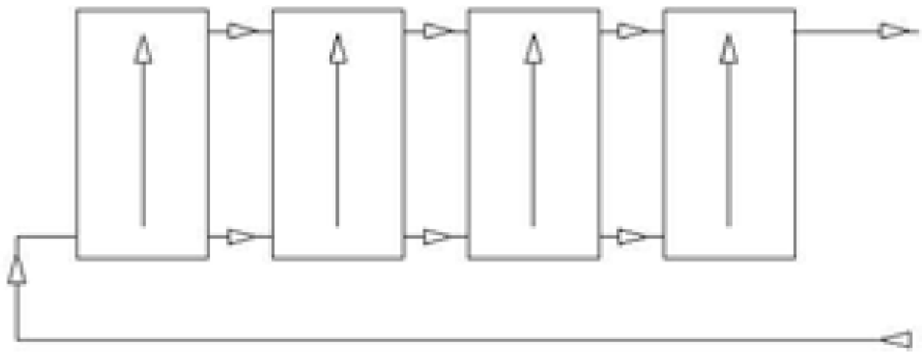


Fig. 18 Collectors in Parallel

6.2 SUPPORT ARRAY FRAMES

They are used to fit the solar collectors. These support frames have the ability to shift to different angles based on the sun's rays to that the maximum output can be obtained from the sun's solar rays. Fixed frames are also used at the specific angle of the required range. For example, in our case, the solar collector used will be in an inclination of 30° in the west. So, the solar panels will have orientation of 30°.

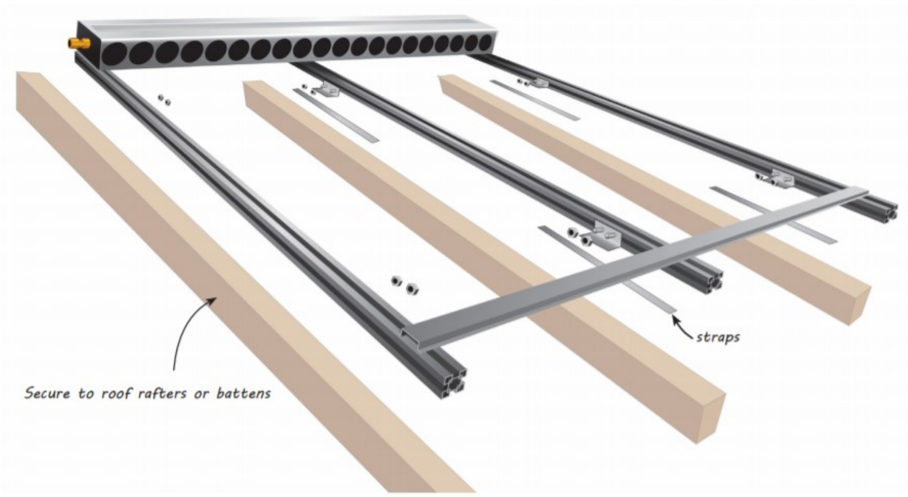


Fig. 19 Support Array frame structures [22]

To install solar collector on the roof of the family house, requires a support frame to ensure the proper fastening of the same. In this way, the support frame, besides making the fastening of the collectors, should provide and additional inclination of 20°, to achieve the desired inclination of 55°.

The support structure of collectors is formed using the standard steel profiles, cut, drilled and then hot dip galvanized to resist the effects of the weather and also to avoid corrosion. The union between the rods that make up the structure is made using security stainless steel screws.

6.3 STORAGE TANK DESIGN

Once the solar energy is captured, we should store the energy captured. It is possible through storage tank of water where the stored energy available in the best possible form, during periods of low demand, after providing for this energy when it is needed.

The storage tanks are made up of aluminum or steel and the most common shape in cylindrical. Their height will be greater than diameter. By varying density of water with temperature, to greater height of accumulator tank, greater will the difference of temperature between the top and bottom of it, it means greater will be the stratification.

The dimension of the storage tank should be calculated based on the volume of the consumption.

According to the surface of solar collectors. Optimum value is taken as 40 litres per meter of collectors. So:

Volume = $40\left({}^{litres}/_{m^2}\right) * 10.865(m^2) = 434.6$ litres……… …………..(*Eqn.15)*

- According to our project water consumed daily is:

Volume = 300 litres

Stratified charge storage is hot water storage tank, typically for solar thermal energy. The warmest storage layer is the top storage cylinder and below this there are colder storage layers through natural layering.

Fig. 20. Sonnenkraft DHW500PR2

So, the average value of the tank should be around 500 litres with 200 litres being in the tank as a reserve should in case the family need extra litres of water.

6.4 TRANSFER FLUID

The fluids transmit heat from solar collectors to heat exchanger. When picking a heat-transfer fluid, the following criteria are important :

- The coefficient of expansion – the change in length of a material for a unit change in temperature
- Viscosity – The resistance of a fluid to sheer forces
- Thermal capacity – the capacity to store heat
- Freezing point – The point below which a liquid turn into a solid

- Boiling point – The point at which a liquid starts to boil
- Flash point – The lowermost temperature at which the vapour above a liquid can be ignited in air.

TYPES OF HEAT-TRANSFER FLUIDS

There are many types of heat transfer fluid present. They are

AIR

Air is the economical heat transfer fluid. It will not react dangerously as other fluids. But it has a very low heat capacity, and tends to escape out of collectors, dampers and ducts.

WATER

Water is non-hazardous and low-priced. It has high specific heat, and a very low viscosity. But water has a relatively low boiling point and a high freezing point. Clean natural water with a high mineral content can cause mineral deposits to form in collector tubing and system plumbing. It can also be corrosive if the pH level is not kept at a neutral level which is 7. Alkaline or acidic water can cause corrosion easily. [23]

GLYCOL/WATER MIXTURES

Ethylene glycol with water mixtures having a fifty-fifty or sixty-forty ratio. The mixture of Ethylene and propylene glycol are "antifreezes". These mixtures deliver effective freeze protection as long as the suitable antifreeze concentration is kept. These types of systems are pressurized and a expert is required for proper maintenance. We use this as our transfer fluid.

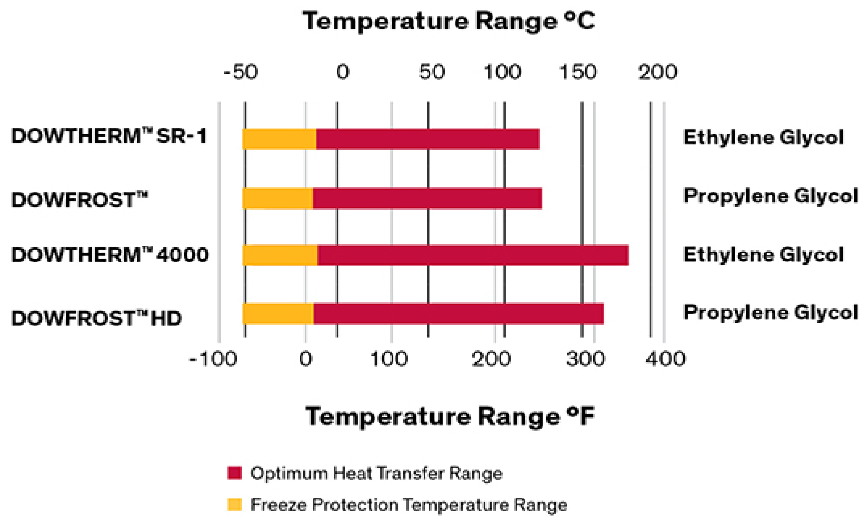
HYDROCARBON OILS

Hydrocarbon oils have a higher viscosity and lower specific heat than water. They want more energy to pump. These oils are relatively low-cost and have a low freezing point.

The basic categories of hydrocarbon oils are

- Synthetic hydrocarbons - Relatively nontoxic and require little maintenance

- Paraffin hydrocarbons - They have a broader temperature range between freezing and boiling points than water. b they are toxic and require a double-walled, closed-loop heat exchanger for the complete safety.



Graph 11. Temperature range of various Heat transfer fluids

SILICONES

Silicones have a very high boiling point and very low freezing point. They have a high viscosity and low heating capacity; they require more energy to pump. But they are noncorrosive and long-lasting.

6.5 AUXILLIARY SYSTEMS

Auxiliary systems are used only when the desired output temperature is not achieved due to the low solar radiation. In our case we will Electric water heater to achieve the desired temperature we need during the winter season.

Auxiliary energy system can be connected of 3 forms in the installation:

- They can be directly connected to the storage tank
- They can also be connected to the output of the storage tank, directly on the water of consumption. [24]

An electric heater connected in series to the output of the storage tank will work only when the hot water that comes from the storage tank is not the desired temperature which is 60°C.

The power needed to heat the water $\boldsymbol{P = m \cdot c_e \cdot \Delta T}$ .... *(Eqn.16)*

Where

- m: Flow of the water in the secondary circuit (0.1 liters/second)
- C_e: Specific heat of water and its value is (C_e = 4.18)
- ΔT: Difference between design temperature of hot water and supply temperature of cold water

In winter, the temperature of design in our system is 60ºC, and the temperature of supply we suppose about 12°C. So,

$$\boldsymbol{P = m \cdot c_e \cdot \Delta T}$$

$$= 0.1*4.18*48$$

So, the power calculated is **P = 20.06 KW**

So, in this case, we will use the 3-phase 400v Electric Instant Hot Water Heater

Fig. 21. Auxiliary heating during the winter seasons [25]

Type		PPH2 hydraulic				
Rated power	kW	9	12	15	18	21
Rated voltage		400V 3~				
Rated current	A	3x13.0	3x17.3	3x21.7	3x26.0	3x30.3
Fuse rated current	A	16	20	25	32	40
Min. connecting wires section	mm^2	4x1.5	4x2.5		4x4	
Efficiency (at 30°C / 86°F temp. rise)	l/min	3.3	4.3	5.4	6.5	7.6
Supply water pressure	MPa	0.15 - 0.6			0.20 - 0.6	0.25 - 0.6
Dimensions	mm	440 x 245 x 126				
Inlet and outlet section		Gw 1/2"				
Distance between inlet and outlet	mm	~100				
Safety class		IP25				

Fig. 22. Characteristics of the auxiliary heater used. [25]

Nominal power: 21kW;

- Will only be used if the desired temperature is not reached
- Automatically switches on 2 steps of heating. Automatic "switch on" system and power selection according to the water flow rate.
- The warm water is available immediately without long lead times cold water available.

Month	Jan	Feb	Mar	April	Sep	October	Nov	Dec	Total
Demand	660.57	603.19	662.42	624.53	556.25	592.23	596.79	641.62	
Solar coverage %	9	24	52	99	86	47	12	3	
Maximum output gain from Solar (kWh)	60.12	144.17	345.02	615.63	476.87	280.90	73.61	20.92	
Auxiliary system (kWh)	600.45	459.02	317.40	8.90	79.38	311.33	523.18	620.70	2920.37

Table 23. Energy Consumption of Auxiliary System

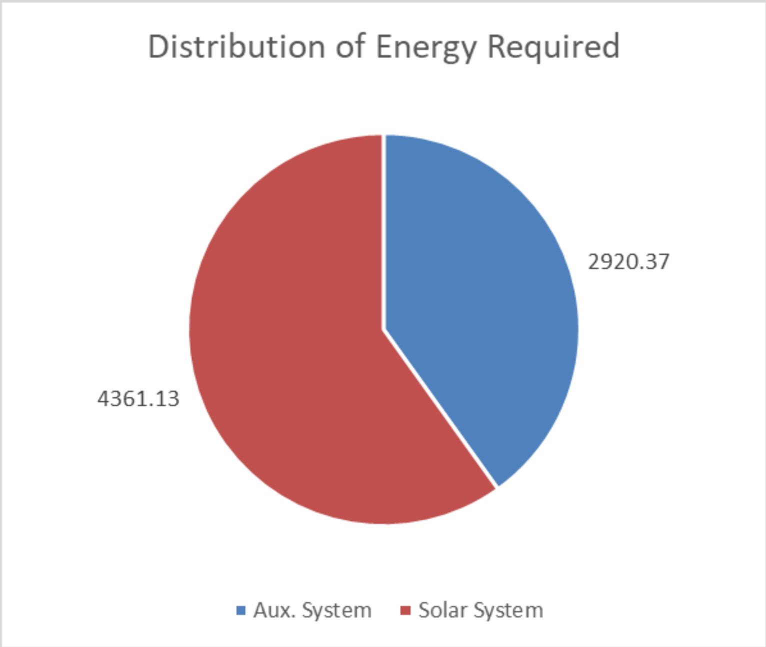


Fig. 23. Distribution of our Energy requirement in kWh

6.6 EXPANSION TANK

The expansion tank serves as an additional storage unit of the storage tank of the hot water. This is due to the fact that, when the water is heated up to the set temperature, the volume expansion occurs. So, when the extra volume of water occurs and it has no place for storage, it will get into the pipes and therefore thermal expansion on the pipes occur resulting in a huge change in the dimensions of the pipe and also pipe burst may occur.

Expansion tank saves as a protector of the entire system. The use of expansion tank also prevents the back flow of the tank and it makes sure that the water once entered the heater/house will not flow back to the city's main pipeline.

6.7 SAFETY VALVE

Safety valve is used in all the hydralic systems which protects the components and its main job is to protect the equipment from bursting or exploding if the pressure get's too high. It will open up without any electric or mechanical support

6.8 MANOMETER

Manometer is a device which has a shape of an U and it is used to measure the pressure of the water. It has a fluid mostly mercury with a scale in the gauges which is used to measure the pressure of the water

Fig. 24. A picture of the manometer used in the system

6.9 TEMPERATURE CONTROLLER

A temperature controller is used to maintain the set temperature as per the user needs and also to ensure that the water does not exceed the desired temperature. It is a vital component in the system

Fig. 25 MISOL 220V Temperature controller [26]

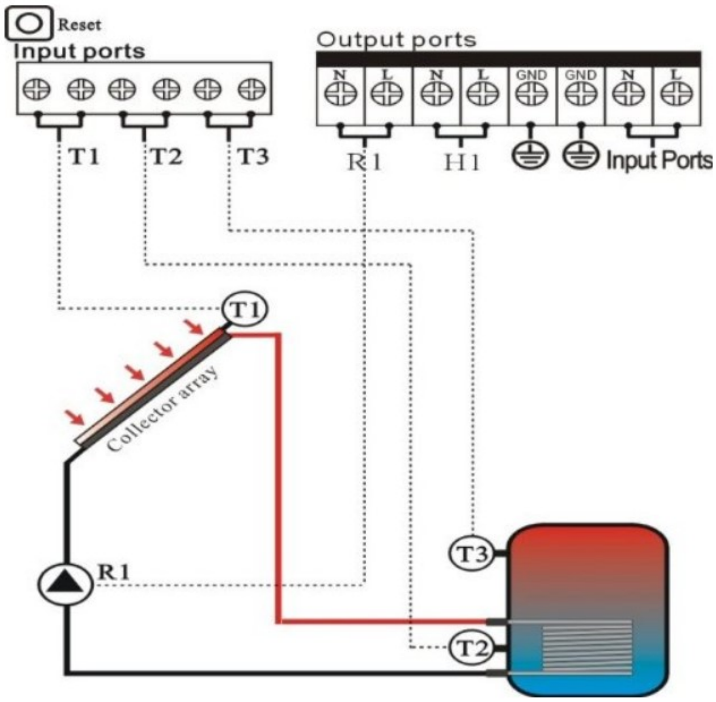


Fig. 26. Circuit diagram of the Temperature Controller

6.10 FLOW REGULATOR

The flow regulator is used to regulate and maintain a constant flow of water without any deviation or change in the flow of the water pressure or velocity.

Fig. 27.Flow regulator used in the system

7. BUDGET FOR INSTALLATION OF THE SOLAR COLLECTORS

ABSORBER SYSTEM			
COMPONENT	UNITS	UNIT PER PRICE	TOTAL PRICE (IN EUROS)
SKR 500 N portrait format (H x W x D) - 2079 x 1240 x 95 mm, max. 12 pcs. in series	5	600	3000
Connection accessory for first collector Solar Key mark: 011-7S 1277F	1	75	75
Connection accessories - For remaining collectors	4	23	92
		Euros	3167

Table 24 Budget for the Absorber System

Transfer system			
COMPONENT	Units	UNIT PER PRICE	TOTAL PRICE (IN EUROS)
Storage Tank 500 litres hot water tank with 2 registers - DHW500PR2	1	1815	1815
Transfer Fluid 25 l container, ready-mixed fluid, up to -25° C	1	92	92
Solar pump station incl. 2-circuit solar controller SL 50 – 26 kW Power	1	550	550
Manometer	1	6	6
Safety Valve	1	21	21
Expansion Valve	1	25	25
Thermometer	1	13	13
Isolation valves	8	15	120
Three-way valves motorized	1	105	105
Mix valve	1	85	85
Clamps	25	2	50
Expansion Tank AG33S 141 303 -	80	1	80
		Euros	2962

Table 25 Budget for the Transfer System

PIPES			
COMPONENT	**UNITS**	**UNIT PER PRICE**	**TOTAL PRICE (IN EUROS)**
Corrugated pipe connection set Transition to 2 x 1" male	29	10	290
Stainless steel corrugated hose DN16 15 meters	1	315	315
		Euros	605

Table 26 Budget for the Pipes

ELECTRICAL SYSTEM			
COMPONENT	**UNITS**	**UNIT PER PRICE**	**TOTAL PRICE (IN EUROS)**
Temperature controller MISOL 220V controller of solar water heater	1	80	80
Sensors	1	20	20
		Euros	100

Table 27 Budget for the Electrical System

AUXILLIARY HEATING SYSTEM			
COMPONENT	**UNITS**	**UNIT PER PRICE**	**TOTAL PRICE (IN EUROS)**
3-phase 400v Electric Instant Hot Water Heater	1	212	212

Table 28 Cost of the Auxiliary Heating System

Total price of the installation will be = 3167+2962+605+100+212=509 **€** euros

Value Added Tax (VAT) 9% = 452.61 **€**

So, the total expense will be **5481.61 €** *(1€ = 25.76 CZK,as on 17thJuly,2019)*

Which is approximately **141,230.12 CZK**

8. ECONOMIC AND ENVIRONMENTAL POINT OF VIEW

8.1 ECONOMIC VIEW

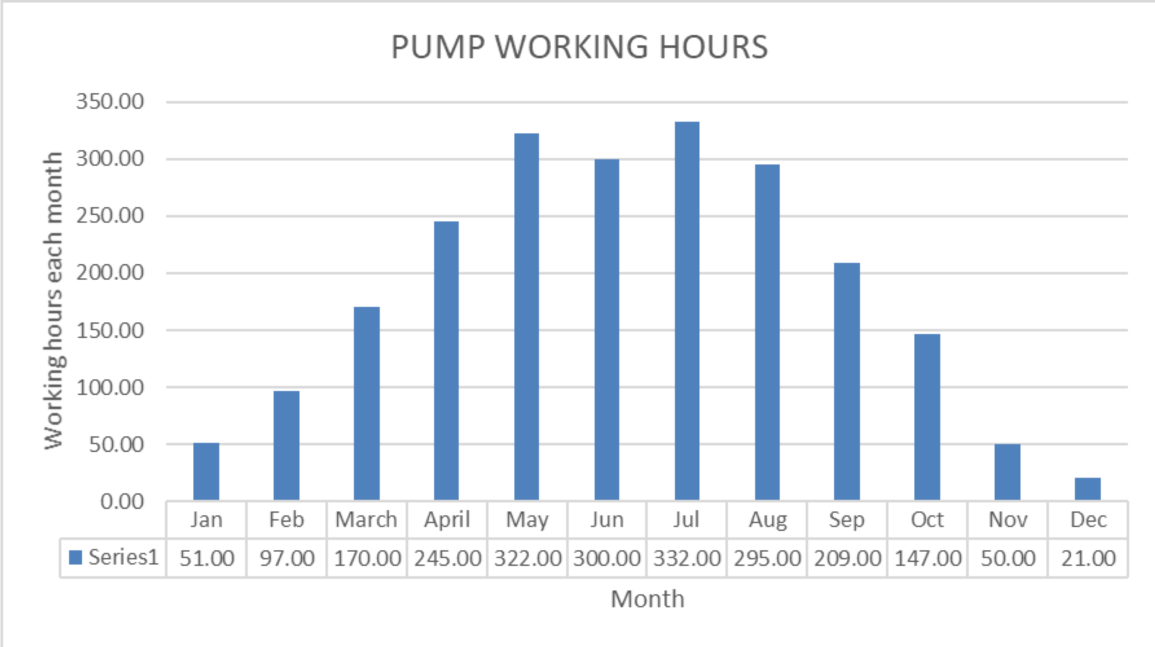
Energy required to heat the water throughout the year in the family house which we considered is **7281.49 kWh / year**

Solar fraction obtained from our layout(West 30°) is about **60%**

Total useful energy obtained from solar energy **4332.76 kWh/year.** So, we save this amount of electricity every year by using the solar panels for heating the water. But this is not the exact value, because the pump is used to circulate cold water. So, the energy used by the pump should also be calculated. The pump works only when there is enough solar energy to convert cold water to hot water. Using that the pump operating hours can be calculated. [27]

Month	***Pump operation per month in hours***
January	51 hours
February	97 hours
March	170 hours
April	245 hours
May	206 hours
June	187 hours
July	190 hours
August	194 hours
September	209 hours
October	147 hours
November	50 hours
December	21 hours
Total	**1768 hours**

Table 29 Hours of Pump Operation



Graph 12. Graph between pump operating hours and month

POWER CONSUMED BY THE PUMP

Pump Power: 26 W

Power consumption for the entire year = 26* 1768

= 45,968Wh/year= 45.96 kWh/year

Cost of using the pump = 45.96*2.38 CZK

1KWh price in Czech Republic = 2.38 CZK [28]

= 109.38 CZK / year.

Only in the summer season, we will receive a large amount of solar radiations. So apparently the working hours for the pump will be high only during at that time. Using the working hours of the pump, we can calculate the power consumed annually by the pump.

The reduction in the power consumption from May to August is due to the fact that the desired set temperature is obtained easily as water temperature at the inlet is higher.

The energy saving with the installation per year is:

Energy Saving = Energy obtained with solar installation

Energy Saving per Year = 4361.13 kWh

Economic saving per year

1KWh price in Czech Republic = 2.38 CZK [28]

Price saved per year = 4361.13 *2.38

= 10379.49 CZK

Month	*Pump operation per month (hours)*	*Solar fraction*	*Energy required for each month [kWh]*	*Max gain from the system[kWh]*	*Amount of energy that can be used efficiently [kWh]*	*Cost in CZK*
Jan	51	0.09	660.57	60.12	60.12	143.09
Feb	97	0.24	603.19	144.17	144.17	343.12
March	170	0.52	662.42	345.02	345.02	821.15
April	245	0.99	624.53	615.63	615.63	1465.20
May	209	1.00	620.99	969.73	620.99	1477.96
June	190	1.00	576.73	925.27	576.73	1372.62
July	193	1.00	577.00	1005.95	577.00	1373.26
Aug	197	1.00	569.17	863.86	569.17	1354.62
Sept	209	0.86	556.25	476.87	476.87	1134.95
Oct	147	0.47	592.23	280.90	280.90	668.54
Nov	50	0.12	596.79	73.61	73.61	175.19
Dec	21	0.03	641.62	20.92	20.92	49.79
Total	***1779***		***7281.49***	***5782.05***	***4361.13***	***10379.49***

Table 30 Energy and Economic Saving obtained for the solar installation proposed

The maxiumum gain from the system obtained during the summer cannot be used for another purpose, so the excess energy obtained is unused.

Energy used by the Auxillliary heating system- = 2920.38 kWh/year.

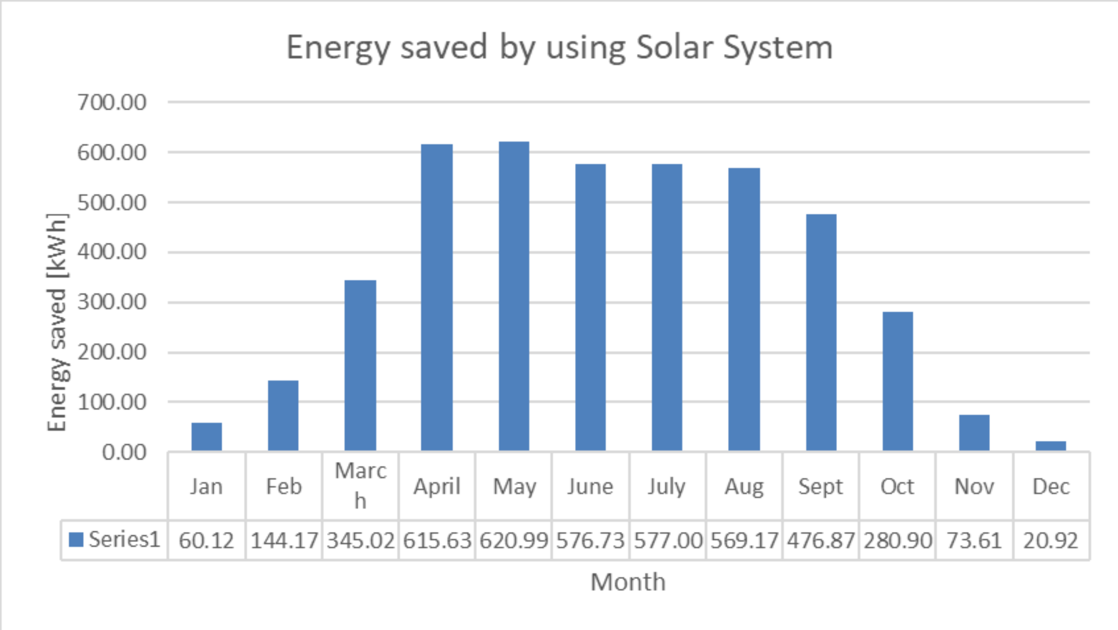
= 2948.73*2.38 czk [28]

= 6950.48 CZK

Actual saving of cost = Cost saved by using Solar System – (Cost spent on running Auxilliary heating system + Cost spent on running the pumps) .... *(Eqn.17)*

= 10379.49- (6950.48+109.38)

= 3319.63 CZK/year



Graph 13. Energy saved per month

The energy saved in kWh is calculated in Czech crowns (CZK) per month. The energy saved per month should be calculated for the entire year to calculate the net profit.

The budget of our project is 141,230.12 CZK and our annual saving of cost is 3319.63 CZK/year. So the payback period for us is about 42.5 years.

No. of years taken	Total cost in CZK
Year 1	3319.63
Year 6	19912.2
Year 11	36505.7
Year 16	53099.2
Year 21	69692.7
Year 26	86286.2
Year 31	102879.7
Year 36	119473.2
Year 41	136066.7
Year 43	142704.1

Table 31. Total payback period for our installation cost

The payback period is approximately 43 years. It is acceptable taking into account the possibilities of obtaining of governments subventions which we did not consider in the budget and that the great benefit of the solar installation is on the environmental impact, because solar energy is a source respectful with the environment.

Even though the payback period approximately 43 years, the fact that we are saving the planet earth from releasing other toxic gases is the major thing we should notice it here. Also, in Czech Republic, the best overall efficiency is achieved only in summer, but there are many tropical regions where they could use the solar collector all over the year and achieve maximum efficiency and also save many megawatts of energy, thus by contributing to clean environment. The awareness for this must be increased and it must be made sure that big companies invest in this and also think it as a long-term project rather than profit oriented short-term business.

8.2 ENVIRONMENTAL VIEW

The main use and the advantage of the solar water heater is to reduce the harmful emissions and pollutant gases back into the atmosphere. By using the solar energy, we can reduce the emission of the main pollutant gases, such as (CO_2, CH_4, N_2O, HFC, PFC and SF_6).

Solar energy also decreases the human being's dependency on fossil fuels a lot. It provides safe environment and pollution free environment. The environmental impact is the major reason why more and more solar collectors should be used. From our project we saved 4361.13 kWh per year. This energy helped us in reducing the emission of pollutants. [29]

To calculate the emission saving we used the datum we obtained from the Czech environmental agency.

Emission Saving [Kg / GJ]					
Dust	SO_2	NO_x	CO	CH_4	CO_2
0.02591	0.4893763	0.41569	0.0393	0.03086	325

Table 32 Emission saving of the mains pollutants gases

The table shows the Kg of pollutants gases saved in function of GJ of energy saved.

Energy saved per year = 4361.13 kWh to GJ

(1 kWh = 0.0036 GJ)

= 4361.13*0.0036

= 15.70 GJ

TYPE OF GAS	***SAVE OF GAS EMISSION***	***ANNUAL SAVE OF ENERGY***	***QUANTITY OF ANNUAL REDUCTION EMISSION OF GASES PER YEAR***
Dust	$0.02591\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*0.40 kg*
SO_2	$0.4893763\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*7.68 kg*
NO_X	$0.41569\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*6.52 kg*
CO	$0.0393\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*0.61 kg*
C_XH_Y	$0.03086\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*0.48 kg*
CO_2	$325\,{}^{kg}/_{GJ}$	$15.70(GJ)$	*5102.50 kg*

Table 33 Table of various harmful gases released to the atmosphere

9. 3D DESIGN

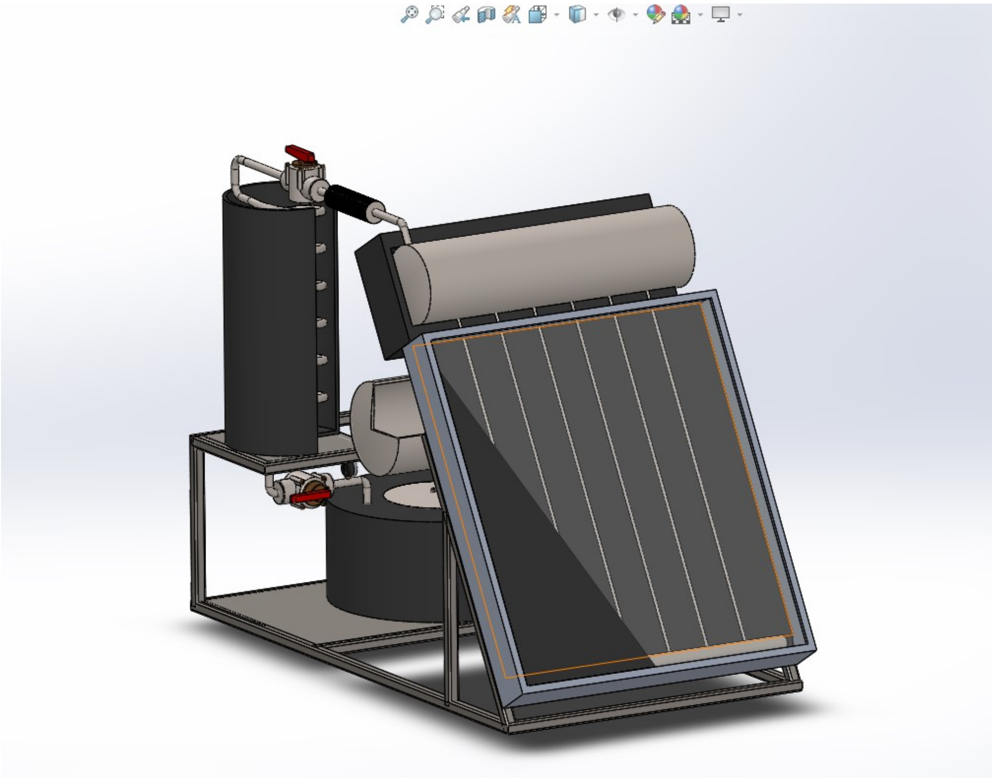


Fig. 28 3D design of the solar collector in Solidworks

In the 3D model, I drew the water reservoir where the cold water is first stored. It then flows to the flat plate solar collector using the pump and the hot water gets stored in the hot water storage tank.

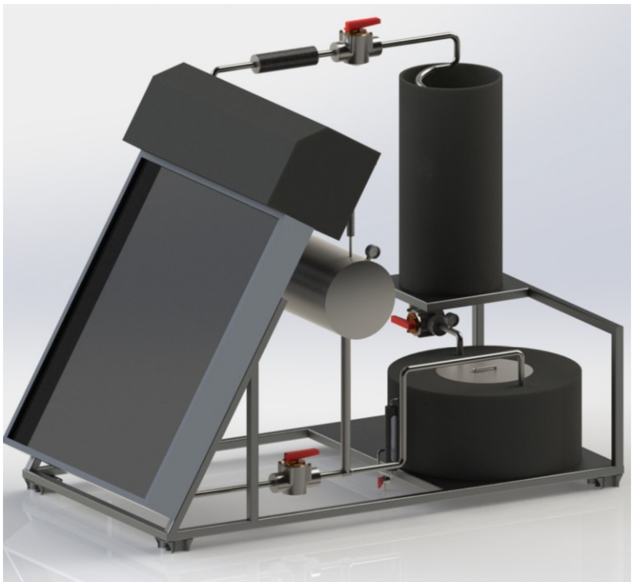


Fig. 29 Isometric view of the system.

10. ANALYSIS OF THE CHANGE IN TEMPERATURE IN ANSYS

I also tried to analyse the change in the temperature in the absorber plate. For the anaysis I chose a collector to with only one tube,to reduce the complication number of mesh. For the analysis, I have taken the ambient temperature of air at 7°C, which is in the December month. [30]

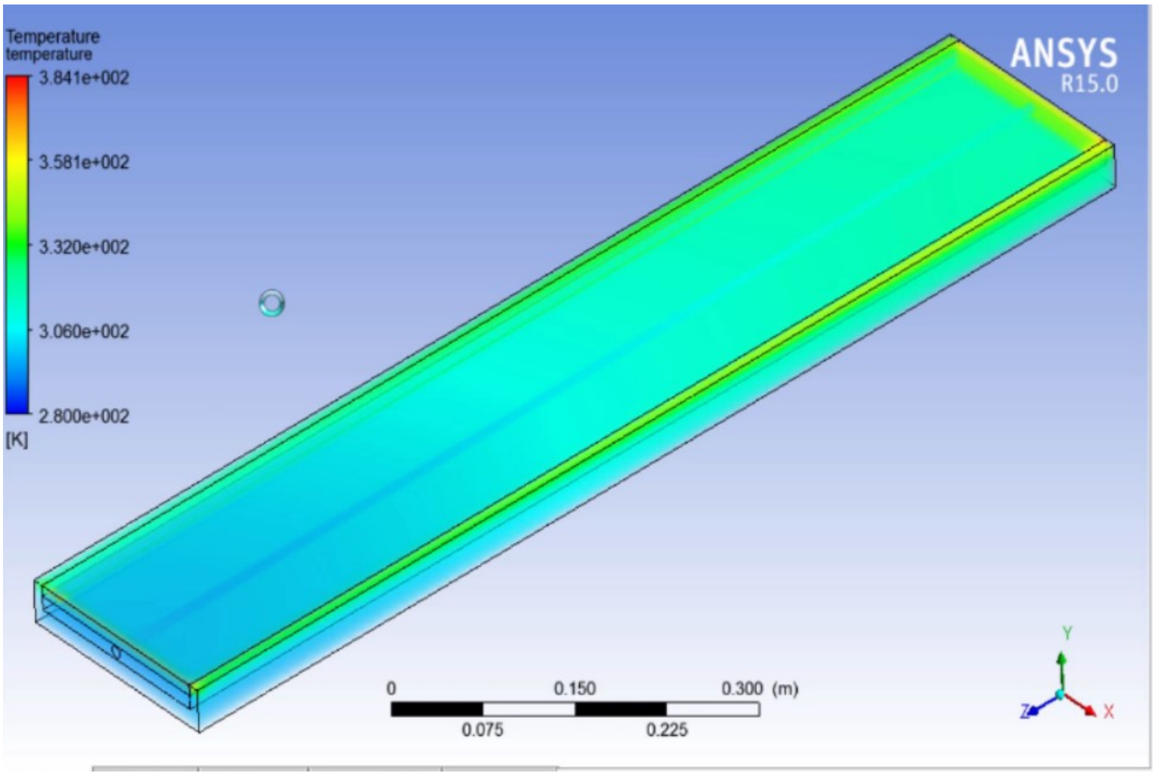


Fig. 30. Ambient temperature change

Factors considered

Month - December

Time – 13.00

Ambient temperature - 7°C

Inlet water temperature – 10.65°C

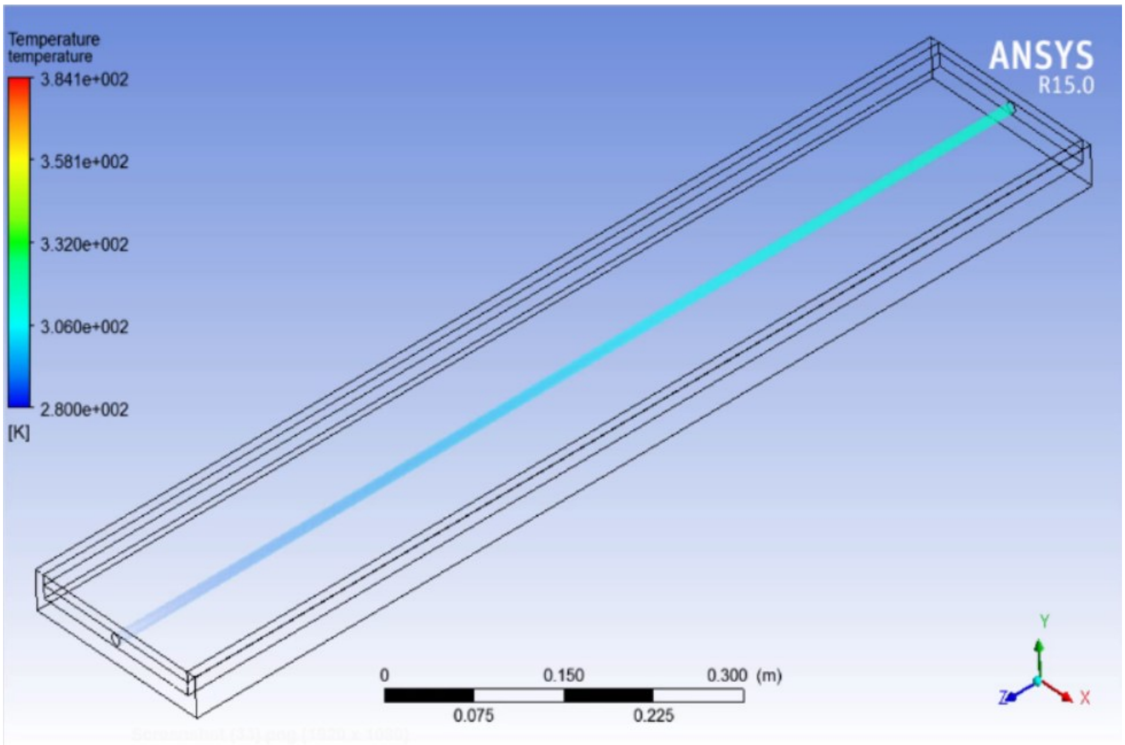


Fig. 31. Temperature change of water

According to the input conditions, the change in water temperature can be noticed. From 10.65°C to 30°C can be achived.

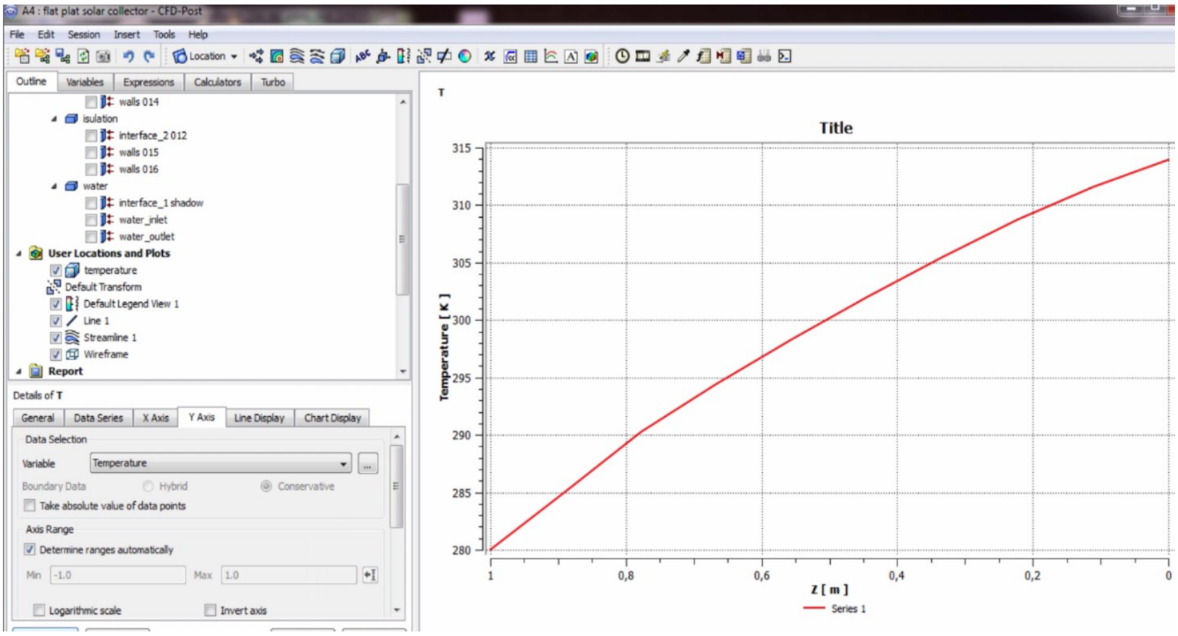


Fig. 32. Temperature change in the form of a graph over a period of time.

11. CONCLUSION

According to the results and solutions we obtained from our project, the estimated ROI (Return Of Investment), for the project is 42.5 years from the year and month of usage. This is due to following facts

1. We didn't consider the Czech Environmental Agency Policy, which states that they will donate a maximum of 50% of the investment cost, but the maximum price that can be obtained is 55000 CZKs. For example, for a project with a budget of 70,000 CZK, the government will give back 35,000 CZK. But since our project budget is 141,230.18 CZK, the maximum we will get back is 55,000 CZK. So, the ROI is now reduced to 28 years, which is a significant advantage.
2. The price and components are taken in euros, suppose we select all the components manufactured by a Czech company, the total price will be very low and also there will be reduction in tax, which will further reduce the total cost of our budget.

Therefore, by taking these into account, it would be a great benefit for the people to save electricity used by non-renewable energy resources. Also, the amount of CO_2 saved during this period of time makes a significant change towards saving the planet.

12. FURTHER IMPROVEMENT

Photovoltaic panels along with the solar panels can be used separately to generate a small amount of electricity which can be used by the people. Solar panels amounts have gradually declined over the last couple of years. Average domestic solar panels cost around £6,000. Solar arrays in this price range can provide you with a system output of 4 kWh, producing around 3,400 kWh per year, provided the solar panels have an inclination of 30-50 degrees. A study shows that in an hour, the sun radiates enough energy that can cover the entire human race energy consumption for a year,but the intensity varies from place to place.

PHOTOVOLTAIC PANELS

A typical silicon photovoltaic panel used in rooftop arrays is about 5.4 feet by 3.25 feet, or 95 inches tall by 39 inches wide. A 300-watt (0.3kW) solar panel in full sunshine actively generates power for one hour, it will have generated 300 watt-hours (0.3kWh) of electricity. That same 300-watt panel produces 240 volts, which equals 1.25 Amps.

In my bachelor's thesis, I have designed and fabricated a foldable electric bicycle attached with battery and we manufactured by a pedelec using old components and scrap. Using that as an example, I have chosen the **BOSCH POWERPACK 300**: Ideal for city use. [31] The standard charger charged with 4A takes about 2.5hours for a complete charge.

Fig. 33. Picture of the Bosch Powerpack 300

	PowerPack 300
Mounting type	Frame battery Rack battery
Voltage	36 V
Capacity	8.2 Ah
Energy content approx.	300 Wh
Weight approx. **Frame battery:** **Rack battery:**	2.5 kg 2.6 kg

Fig. 34. Technical details of the chosen battery [31]

The photovoltaic panel chosen Canadian Solar > 325 Watt HiDM High Density Mono-PERC Solar Panel - 35mm Black Frame [32]

Monocrystalline Solar Panel 35mm Black Frame	
Model	CS1H-325MS - Black Frame
Series	CS1H-MS
Manufacturer	Canadian Solar
MECHANICAL	
Type	Monocrystalline
Dimensions	66.9" x 39.1" x 1.38"
Weight	41.7 pounds
Frame	Black Anodized aluminum
Connector	Junction Box - IP68, 3 diodes
ELECTRICAL	
Watts (STC)	325 W
Max Power Voltage (VMPP)	35.8 V
Max Power Current (IMPP)	9.09 A
Open Circuit Voltage (VOC)	43.4 V
Short Circuit Current (ISC)	9.58 A
Max System Voltage (UL)	DC 1000 V

Table 34. Description of the chosen photovoltaic panel

The maximum power current is 9.09 A but in reality it will less. So let's assume the power current we achieved is about 4.5 A. So, a 2.5 hours of charging the powerpack 300 will give it 100% charge using which we can achieve a range of about 60-80kms with a single charge.

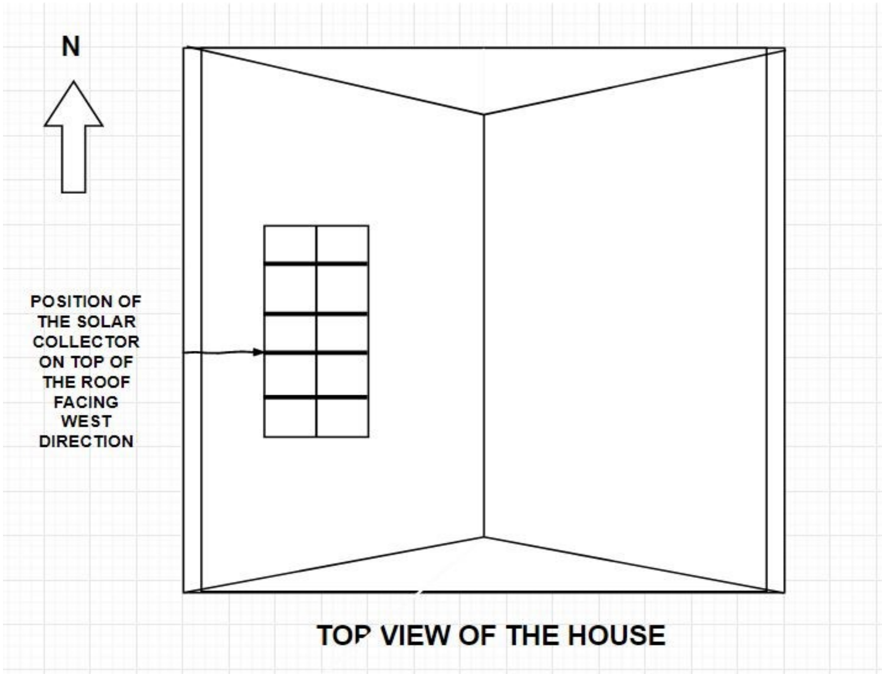
Using it for charging an electric bicyle is just one of the practical application. There are many other smaller applications like charging a laptop or using it for lights in the outdoor / garden area.

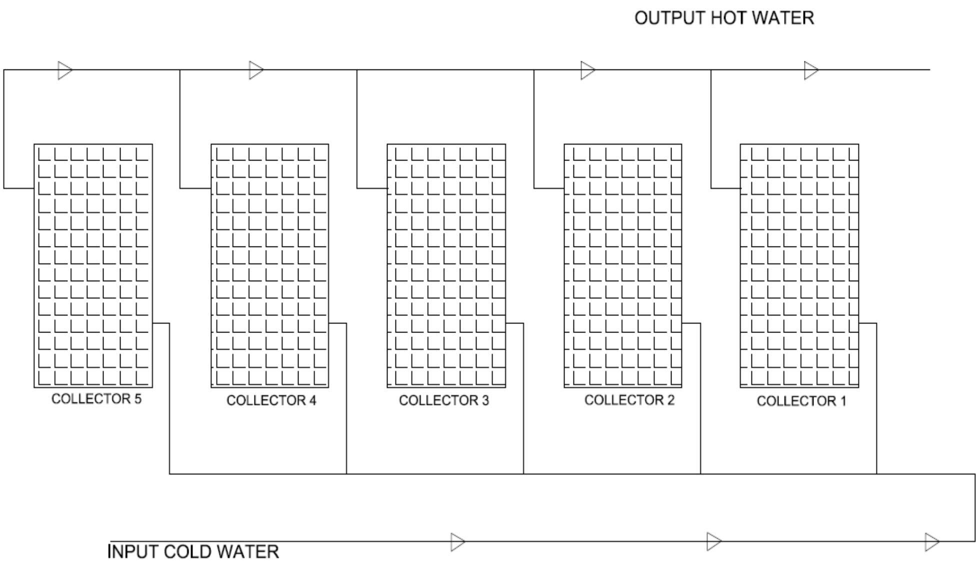
The cost of the photovoltaic panel is 16,078.04 Czech Koruna but the overall installation cost will be much higher. Although the initial cost will be a little higher, this is one of the ideas where we could use the heat from the sun not only for heating the water but also for generating electricity thus reducing more CO_2 emissions.

Advantages

1. They are quite and unobstrusive.
2. Little maintenance is required and and they reduce the energy bills.
3. If excess energy is achieved in a very big farm of solar panels,they can connected to the local electrical grid.

13. BLUEPRINT AND SCHEMATICS

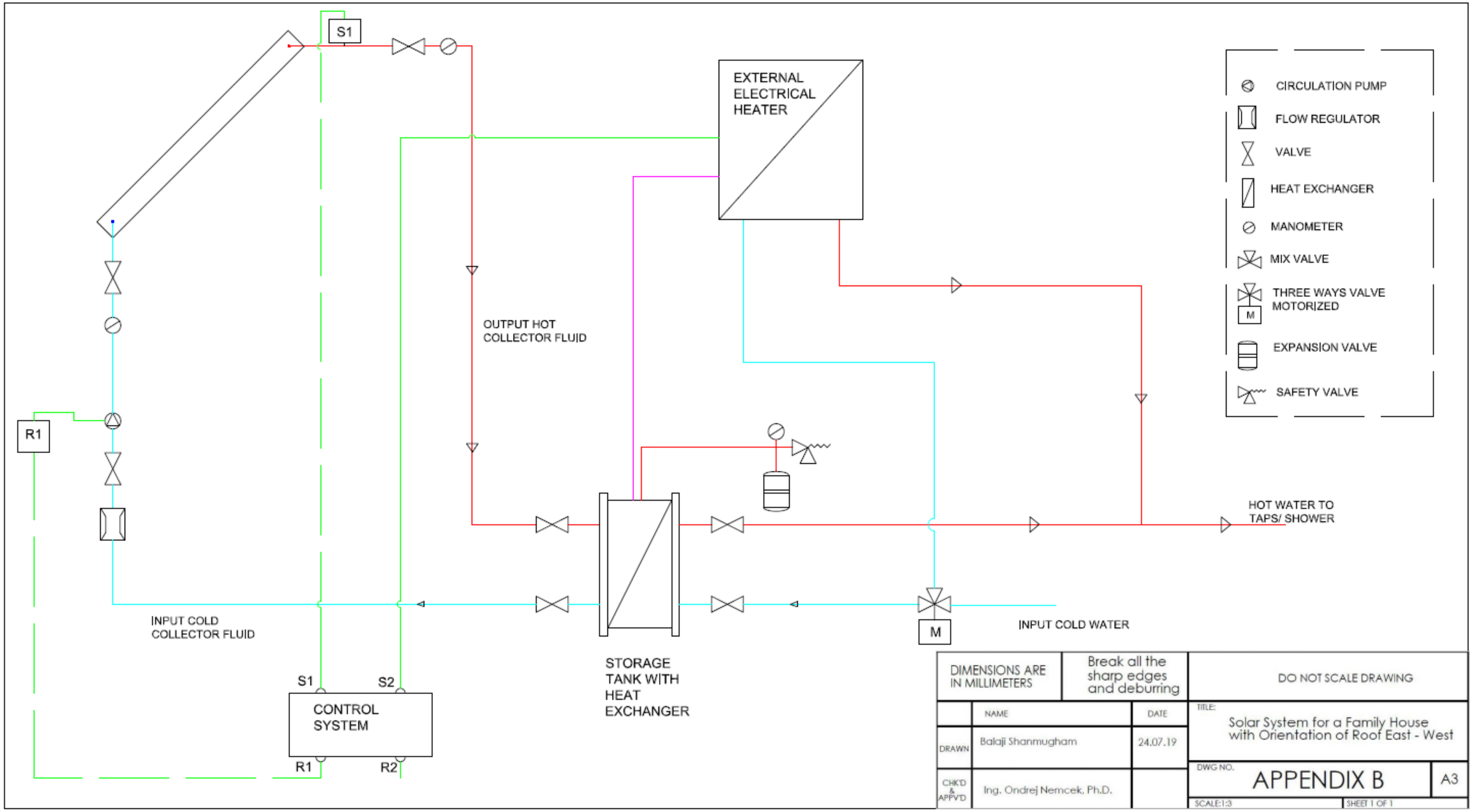




PIPE OUTLINE

SOLAR COLLECTOR INSTALLATION IN A FAMILY HOUSE FOR HOTWATER

TOP VIEW OF THE HOUSE SHOWING THE POSITION OF THE SOLAR COLLECTORS



SCHEMATIC DIAGRAM OF THE SOLAR COLLECTOR CIRCUIT

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15. APPENDICES

APPENDICE A

- Solar Collector
- Hot water Tank
- Solar Pumping Station
- Expansion Tank
- Auxiliary Water Heater

APPENDICE B – Scheme of Engagement

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